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THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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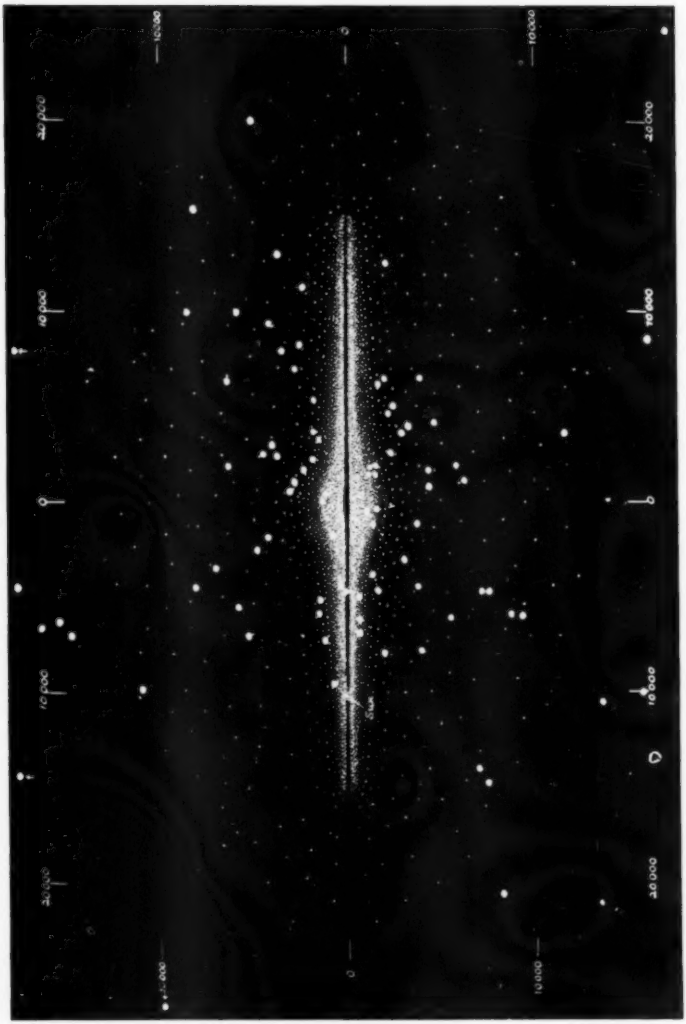

PROPOSED MODEL OF THE GALAXY

THE JOURNAL
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OF CANADA

Vol. XXX, No. 5 MAY-JUNE, 1936 WHOLE No. 254

THE DIMENSIONS AND STRUCTURE OF THE GALACTIC SYSTEM*

By J. S. PLASKETT, C.B.E., F.R.S.

(With Plate XIV)

THE initiation of observational data on the proper motions of the stars, which are essential in the determination of the dimensions and structure of the galactic system, can be legitimately assigned to Edmund Halley, who announced in 1718 his discovery of the proper motions of Aldebaran, Sirius, and Arcturus. Halley did not apply this discovery to the problems of the Galaxy, and Sir William Herschel must be considered as the actual founder of sidereal astronomy. In two papers to the Royal Society in 1785, he advanced the first definite model of the stellar system, the result of a laborious observational investigation of the distribution of the stars. On the assumption of uniform distribution and by means of his 20-foot telescope of 19½ inches aperture, with an eyepiece of power 160 and field of one-quarter of a degree in diameter, he determined the relative distances of the stars in 3,400 regions of known position. This "star gauging" led him to the conclusion that the stars were finite in number, and that the system was greatly flattened to the Milky Way, with a diameter about five times its thickness. Although Herschel did not know the distance of a single star, he estimated the diameter of the Galaxy as 850 times and the thickness as 155 times the average distance of a first magnitude star, corresponding to about 6,000 and 1,100 light years respectively.

*This is a summary of the principal features of the Halley Lecture delivered at Oxford on June 5, 1935.

Although the increase in observational data during the nineteenth century led to numerous attacks on the problems of the Galaxy, the next signal advance was made by Seeliger in the first decade of the present century. Considering the intrinsic brightnesses of the stars as represented by a frequency distribution, Seeliger developed analytical expressions connecting the numbers of stars of any given magnitude with the mean parallax and with this luminosity function. Considering the star density as depending only on the distance from the sun and on the galactic latitude, Seeliger arrived at a flattened system of a diameter estimated at 7,250 parsecs, 23,000 light years, and a thickness of nearly 6,000 light years. These analytical methods were extended by Schwarzschild, Charlier and others, but Kapteyn, the outstanding exponent of stellar distribution, combined empirical statistics with the analysis and arrived at his well known model of the stellar system, with the stellar density decreasing with distance from the sun. If the limits of the system are fixed at one-hundredth the star density near the sun, the Kapteyn Galaxy has a diameter of 17,000 parsecs, 55,000 light years, with a thickness of 3,500 parsecs, 1,100 light-years, and hence with similar flattening to the Herschel and Seeliger systems. Although the diameters have increased from 6,000 light years by Herschel to 23,000 by Seeliger and to 55,000 by Kapteyn, all these models feature the sun as the centre of a watch-shaped cluster of stars with the density decreasing outward. This central position of the sun must have raised doubts about the reality of these models as the probability of one particular star among thousands of millions being central is infinitesimal, and it required a new method of attack to reveal their partly fictitious character.

Such a method was developed by Shapley in his investigation of the globular clusters at the Mount Wilson Observatory, 1916-18. This method depends on determining the intrinsic brightness of very luminous stars, and hence, by the inverse-square law, of their distance. The Cepheid variables, in which the brightness increases with the period, were the principal stars used as distance indicators by Shapley, who obtained their intrinsic brightness, or the "zero-point of the period luminosity curve", from the proper motions of galactic Cepheids of known period. The intrinsic brightness of the Cepheids were used to calibrate other distance indicators for the clusters, such as the median magnitudes of the 25 brightest stars,

the total magnitudes, and the apparent diameters. In this way Shapley obtained the distances of seventy globular clusters, ranging between 20,000 and 200,000 light years, which, when projected on the galactic plane, immediately dethroned the sun from its central position, with respect to the clusters, their geometrical centre being 20,000 parsecs, 65,000 light years from the sun in the direction of Sagittarius, galactic longitude 327°. When the clusters were plotted on a plane perpendicular to the galactic plane, and passing through the sun and the centre at 327°, the globular clusters were found to be symmetrically distributed in a spheroidal form with the same number on each side of the central plane. This obviously indicates a dynamical connection between the globular clusters and the central flattened disc of stars, which are hence probably concentric and coterminous. On this basis Shapley estimated the Galaxy to have a diameter of 80,000 parsecs, 260,000 light years, and a thickness of some 5,000 parsecs with the sun 20,000 parsecs from the centre.

Shapley's model of the Galaxy may be considered as a great flattened disc of stars, star clouds, diffuse nebulae, etc., 80,000 parsecs in diameter, five times larger than the Kapteyn system with the sun no longer central as in all earlier models, and with the globular clusters indicating the bounds of the system. This great increase in the dimensions of galactic models, from Herschel's modest galaxy of diameter 6,000 light years, through Seeliger's of 23,000 and Kapteyn's of 55,000, to Shapley's of 260,000 light years, from the period 1785 to 1920, may be considered as the first stage in the development of models of the Galaxy. As will presently be seen the trend since 1920, and particularly since 1930, has been toward a considerable reduction in these maximum dimensions, the conspiring causes being a decrease in the intrinsic luminosity of the Cepheids, a change in "zero-point", and, particularly, the effect of interstellar absorption in decreasing luminosity distance.

Since Shapley's first determination of the "zero-point", the intrinsic luminosity of the Cepheids, additional proper motions have led to revisions, Wilson in 1923 suggesting a reduction of Shapley's distances by 20 to 30%, and Gerasimovic in 1931 by about 40%. However, Gersaimovic later stated that the affect of absorption would considerably reduce this correction while more recent work indicates a correction of from 10 to 20%. Consequently the revised

distances of 93 globular clusters obtained by Shapley and Sawyer in 1928, reducing the original distances by 11%, has been adopted. Shapley in his book "Star Clusters", 1930, plots anew the revised distribution of the globular clusters on the three planes of the Galaxy, and this plot is seen in the left-hand section of Fig. 1. On the plane

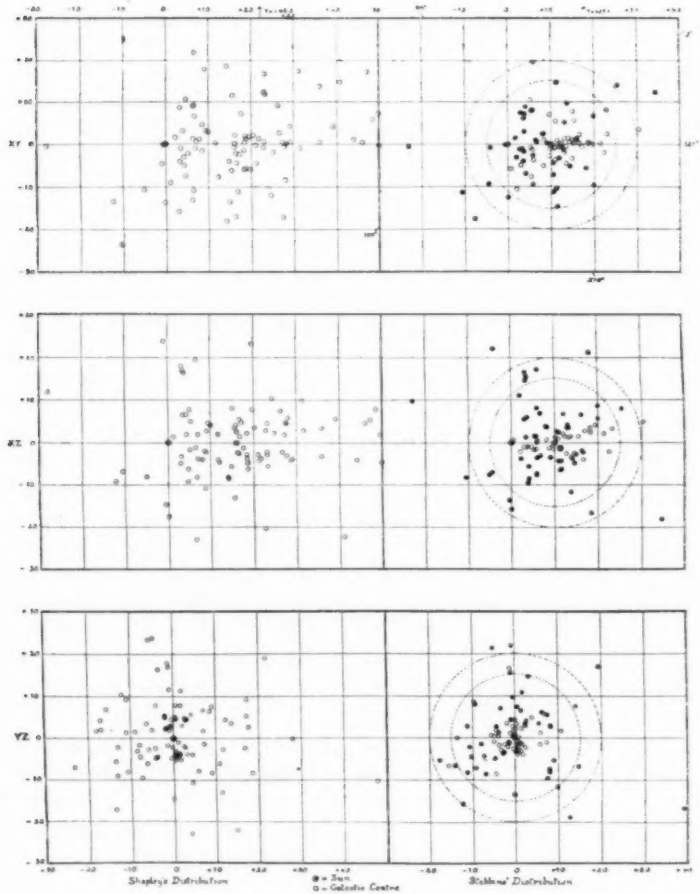


Fig. 1. Distribution of Globular Clusters.

of the Galaxy, XY plane, with the sun at the origin and the X-axis passing through the centre, and on the XZ plane, the clusters show a spheroidal distribution, and, if some of the clusters are considered as outliers, the longer axis is about 60,000 and the shorter about 40,000 parsecs, while the distance from the sun to the geometrical centre is about 16,000 parsecs, which was adopted by Shapley.

The great disparity in size between the Galaxy and the largest known external system, the Andromeda Nebula, which Hubble had recently shown to be less than 13,000 parsecs in diameter was the apparent cause for the introduction of hypotheses by Lundmark and Shapley that the Galaxy could not be a single unified system like the Andromeda and other spirals, but rather consisted of a loose aggregation of nebulae. Trumpler also advanced a somewhat analogous conception of a complex Galaxy, but recent developments indicating a considerable reduction in the dimensions of the Galaxy and an increase in those of the Andromeda Nebula, bringing them nearer to equality, has removed the cause of these hypotheses of complex structure, and they are now practically abandoned.

The principal cause for the reduction of estimated galactic dimensions is the presence of absorbing matter within the system, which will dim the light of distant stars, so that distances obtained by luminosity methods, on which the above dimensions of the galaxy are based, will be estimated as too great. Both Seeliger and Kapteyn early realized the effect of absorption on the stellar density distribution and computed the amount which would make the stellar density approximately uniform, obtaining values varying between $0^m.3$ and $2^m.1$ per 1,000 parsecs. These determinations were not taken very seriously until about 1930, mainly owing to the work of Shapley and Lundmark who found that the absorption in inter-galactic space was only $0^m.00007$ and $0^m.0007$ respectively per 1,000 parsecs with the inference that the absorption within the Galaxy was also negligible.

The first direct evidence of the presence of a widely diffused gaseous medium within the Galaxy was given by the author in 1924 in the demonstration that the H and K lines of calcium and the D lines of sodium, which appeared in the spectra of the high temperature stars, were produced by a widely diffused gaseous medium containing once ionized calcium and neutral sodium. Although only monochromatic absorption was thereby demonstrated, it seems

probable the medium will also produce general absorption.

It was not, however, until Trumpler's investigation of the open clusters in 1930, that astronomers began to consider seriously the effect of absorption on galactic dimensions. Trumpler obtained the luminosity distances of 100 clusters and, on the assumption that all open clusters of the same type have the same linear diameter, found that the diameters of the most distant clusters, computed from the angular diameter and the luminosity distance, were nearly twice those of the nearest ones. There must hence be either an increase of diameter with distance from the sun, a very improbable assumption, or absorption of light in the system. Trumpler found that an absorption of $0^{m}.67$, photographic, per 1,000 parsecs, composed of a selective part of $0^{m}.32$ and a general absorption of $0^{m}.35$, reconciled the disparity. He believed the absorption was concentrated in a layer 200 to 300 parsecs thick at the galactic plane.

This was quickly followed by several investigations on the amount and effect of absorption in the Galaxy. Van de Kamp, from the distribution of clusters and nebulae, obtained an optical thickness of $0^{m}.8$ and a linear thickness of 210 parsecs, corresponding to an absorption of $1^{m}.7$ per 1,000 parsecs, and reducing the distance from the sun to the centre from 16,000 to 5,500 parsecs. Seares, by an amplification of the earlier statistical methods with increased data, confirmed the Shapley model of the Galaxy, and arrived at an indirect estimate of $0^{m}.4$ or $0^{m}.5$ per 1,000 parsecs of absorption. Similarly Bok finds an absorption of $0^{m}.4$, while Hubble, in 1933, from the distribution of the extra-galactic nebulae finds an optical thickness of the absorbing layer of $0^{m}.5$, photographic; this corresponds to a distance from the sun to the centre of 8,000 instead of 16,000 parsecs. All these methods are indirect and rather uncertain and a more direct determination of the absorption seems desirable.

This was provided, also in 1933, by Stebbins' measures of the colour excess of the globular clusters with his photo-electric photometer attached to the 100-inch Mount Wilson reflector. With blue and yellow filters, he obtained the colour excess of 47 globular clusters, which ranged between $-0^{m}.21$ and $+0^{m}.44$ on his scale, corresponding to $-0^{m}.70$ and $+1^{m}.48$ in normal colour indexes. This gives a selective optical thickness of $0^{m}.18$, which from Trumpler's and Van de Kamp's work corresponds to a total photo-

graphic optical thickness of $0^m.36$, thus smaller than the earlier values of Van de Kamp and Hubble. This optical thickness reduces the distance of 16,000 parsecs from the sun to the centre to 10,000 parsecs, as determined from a table by Van de Kamp or graphically from the corrected distribution of the clusters. From the optical thickness of $0^m.36$, the correcting factor for the distances of the clusters varies from 0.25 for latitude 3.1°, the lowest for a cluster, to 0.93 at the pole.

The application of this correction to Shapley's revised distances of 93 globular clusters gives the corrected distribution on the three rectangular planes, shown in Fig. 1, those on the left being Shapley's revised distances, and on the right these distances after correction for Stebbins' absorption. It seems obvious that the corrected spherical distribution on the right is a much more likely one than the spheroidal one on the left, and we have good grounds for adopting the 10,000 parsecs obtained graphically from the distribution, as well as computed, for the distance from the sun to the centre. It seems certain, however, from photographs of the Milky Way and particularly from Hubble's work on the distribution of the extra-galactic nebulae, that the absorption is decidedly irregular, instead of uniform as assumed. If the clusters within Hubble's "zone of avoidance", which are shown in the plots as unfilled circles, indicating uncertainty in distance, are left out of the picture, the distance to the centre and the dimensions are not greatly affected. However the patchy nature of the obscuration within ±30° of the galactic equator makes the determination uncertain and an independent method of obtaining the distance between the sun and the galactic centre would be desirable.

Such a method is provided by the rotation of the Galaxy, the distance to the centre being obtained from the constants of the rotation. Lindblad, in 1925, was the first to propound a definite theory of the rotation of the galactic system. He assumed that the Galaxy was composed of a number of sub-systems, each in rotation, though at different speeds, around a common axis perpendicular to the galactic plane. The sun, the Milky Way clouds and the great majority of the stars, which move in nearly circular orbits, are members of the most rapidly rotating sub-system, which is obviously the most flattened to the central plane, while other sub-systems, such as the high velocity stars and the globular clusters,

have very small rotational velocity. This theory was successful in explaining such puzzling phenomena as Stromberg's "asymmetry" and star streaming. About a year later, Oort further developed the theory of the rotation to permit of observational tests, and it is this development with which we are particularly concerned in obtaining the distance R to the centre.

On the reasonable assumption that the distance r to the star is small compared to R, Oort developed the following simple relations connecting the rotational effect with the motion, distance, and position of the star.

$$\rho = r\,A \sin 2\,(l-l_0) \cos^2 b$$
$$\mu_c = (A/4.74) \cos 2\,(l-l_0) \cos b + (B/4.74) \cos b$$
$$V/R = \omega = A - B$$

where ρ is the residual radial velocity (freed from the solar motion) and μ_c the component in galactic longitude of the residual proper motion; l, b and l_0 are the galactic longitudes and latitudes of the star and the longitude of the gravitational centre, about 327°; A and B are the rotational constants expressed in km./sec. per parsec, A being the radial component and B the average transverse component, while V is the circular velocity of rotation of the sun. Oort, from the radial velocities and proper motions of the most distant objects then available, was able to show a rotational effect similar to planetary motion and proportional to their distance and direction. He was also able to determine the distance from the sun to the centre as about 6,000 parsecs.

While later determinations somewhat increased this distance, additional observational material on very distant stars was required to give more reliable results. This was provided by observations of the radial velocities of the fainter O5 to B7 stars by Pearce and the writer at Victoria, combined with proper motions kindly given by Prof. Boss in advance of publication. An exhaustive discussion of the radial velocities of 849, of the proper motions of 839, and of the radial velocities of the interstellar matter in the direction of 314 of these stars, gave very convincing evidence of the rotation and accounted for the mysterious K term, a residual positive velocity of 4 or 5 km./sec., hitherto present in analyses of the motions of the O and B stars. These observations gave, by means of the formulae above, the rotational constants A and B, required to determine the distance R and the other dynamical constants of the

Galaxy. The mean value of A was $+0.0155 \pm 0.0009$ and of B, $-0.012 \pm .0027$ km./sec. per parsec.

As the third formula shows, the circular velocity of rotation at the sun, V, is required to determine R from A and B. This has been determined by Stromberg, Hubble, and Oort from the motion of the sun with respect to the globular clusters and the extra-galactic nebulae and the velocity of 275 km./sec. has been adopted as the most probable value. The formula transposes to $R = \frac{V}{A-B} = \frac{275}{.0155+.012} = 10{,}000$ parsecs in exact agreement with the luminosity distance corrected for absorption. From this value of R and from formulae by Lindblad and Oort we can readily obtain the other dynamical constants.

Period of Rotation at the Sum	$P = 224{,}600{,}900$ years
Total Mass of Galaxy	$M = 16.5 \times 10^{10}$ suns
Ratio of Inverse Square to Total Force	$K_1/K = 0.0.75$

While the exactness of the agreement between these two entirely independent methods of determining the distance from the sun to the centre of the Galaxy is probably fictitious, as each is subject to considerable uncertainty, the entirely different methods and data, with the unlikelihood that the errors would exactly compensate, serves to give us considerable confidence in the correct order of this distance.

Even with this adopted distance, the diameter of the flattened central disc of stars cannot be so certainly assigned. While Shapley appears to consider it as extending nearly as far as the most distant clusters, they may be considered as stragglers and the boundary limited to the position where the clusters begin to condense. Two dotted circles have been drawn around the galactic centre on the right hand plots of Fig. 1, of diameters 30,000 and 40,000 parsecs. All would likely agree that the diameter was considerably less than 40,000 parsecs, so that the value of 30,000 parsecs which includes 90% of the clusters has been adopted. Values from different methods and data by Lindblad of 26,000 parsecs, by Trumpler of 30,000 parsecs, by Oort of 28,600, and by Shapley of 32,000 parsecs or more, combine in confirming a diameter of 30,000 parsecs, which has been adopted.

The largest known external system, the Andromeda Nebula, has

a diameter according to Hubble of 13,000 parsecs, which allowance for change of zero point and for absorption within the Galaxy might reduce to 10,000 parsecs. The original disparity in size has been reduced from six to one to three to one, which is still so great as to leave doubts about the similarity in structure. However, three recent investigations have shown that the Andromeda Nebula is comparable in size with the Galaxy. Hubble, in 1932, provisionally identified 140 nebulous objects, in and near the Andromeda Nebula, as globular clusters, whose distribution indicated a diameter of over 20,000 parsecs. Stebbins and Whitford in 1933 showed by photo-electric measures that the nebulosity extended to distances much greater than the visible boundary, pointing to a diameter of 20,000 parsecs. Finally Shapley from density measures on long exposure photographs found a diameter of nearly 20,000 parsecs. The dimensions of the two systems are hence so nearly the same that no hypothesis of radical difference in structure need be considered.

Not only are the dimensions of the two systems approximately the same, but they are remarkably similar in surface brightness, membership and structure. Although determinations of the brightness of the Galaxy are uncertain, Seares and Stebbins agreed that the Galaxy near the sun is only one-hundredth as bright as the Andromeda Nebula near the nucleus. At the same time, the latest work indicates that the brightness at corresponding positions in the two systems is approximately the same. The work of Hubble on the Andromeda Nebula has shown that, like the Galaxy, it contains stars and star clouds, bright and dark diffuse nebulae, Cepheids, giant and super-giant stars, and novae, and each appears to be surrounded and outlined by globular clusters. The similarity in dynamical constitution is shown by the demonstration that each is in rotation in its own plane, each has a greatly flattened form and a large and massive central condensation. While the Andromeda Nebula apparently has spiral structure it is impossible from our position within the central disc of stars to determine the structure of the Galaxy, although Easton, Trumpler and Lindblad consider it is also of spiral structure. It therefore seems legitimate to believe that the Galaxy is a great nebula, possibly of spiral form, about ten times the average diameter of extra-galactic nebulae, but only slightly larger than the Andromeda Nebula which it appears to resemble in all essential details.

We should now be in a position, having sketched the changes and corrections required in our original conceptions, to construct a model which will include the principal features of the various researches described in this paper. It may safely be said that the gravitational force, due to the mass of the system, maintains the rotational and orbital motions about the centre and determines the form and distribution of the stars in the system. The main feature of the Galaxy is the great flattened disc of stars, containing probably over 90% of the mass of the system. Undoubtedly maintained in its flattened form by the rotation, this disc is strongly condensed towards the galactic plane and is approximately circular in outline, with an effective diameter of 30,000 parsecs, nearly 100,000 light years. While the star density rapidly decreases at this limit there are scattered variable and other high velocity stars extending to perhaps 5,000 parsecs beyond the effective boundary. Similar high velocity stars, and the globular clusters also, extend on either side of the central plane *D* 10,000 parsecs or more. According to Oort's fine work on stellar distribution, half the photographic light in our neighbourhood is given by a central layer about 330 parsecs thick while half the mass is within a thickness of 530 parsecs. The stellar density decreases to one tenth that at the sun at a height of 500 to one-fortieth at 1,000 and to one-hundredth at 1,500 parsecs. It is obvious therefore that the majority of the stars lie within a layer 1,000 parsecs thick at the sun although this layer undoubtedly increases in thickness and density as the centre is approached. From analogy with external systems, it seems likely there is a spheroidal enlargement at the centre 5,000 parsecs or more in thickness. An approximate representation of the appearance of this model, as seen edge on from a great distance, the larger dots representing the globular clusters, is given in the Plate.

The theory of galactic rotation readily explains this peculiar distribution of the stars. The flattened central disc is mainly composed of stars with small random velocities, of the order of 20 km./sec., and includes the sun and the majority of the stars we observe. As the rotational velocity is some 275 km./sec., there can be little deviation from circular motion and we may assume that practically all the stars within 500 parsecs of the central plane move in circular orbits of small inclination. As the random motion

increases, the orbits become more eccentric and more inclined to the central plane thus explaining the scattered stars and the globular clusters found at distances of 10,000 parsecs or more from the effective boundary of the central disc. On the other hand, the diffuse matter giving the interstellar *H* and *K* lines and the *D* lines has only very small random velocities, about 4 km./sec., and is hence even more concentrated to the central plane. It seems reasonable to suppose that the diffuse matter giving the general absorption has a similar distribution and that the dark nebulae of the Milky Way are condensations in this absorbing material similar to the clusterings of stars into star-clouds. Such a condensed layer is a prominent feature of nebulae seen edge-on and is represented in the model in the Plate. It seems from the most liberal estimate of the mass of the stars of the system that a considerable proportion of the total mass of 165,000,000,000 times the sun's mass, must be due to the diffuse matter. Supposing this matter to be 500 parsecs thick and 30,000 parsecs in diameter, a density of 2×10^{-23} gm/cm.^{3}, equivalent to 3 ounces distributed over a cube 1,000 miles a side, would give a mass of 100,000,000,000 suns, more than sufficient to make up the deficiency in the mass of the stars.

Summarizing finally, we have as the main feature of the Galaxy a great central disc of stars, irregularly distributed in groups or clusters with a general underlying field of stars, with possible spiral structure. The effective diameter is 30,000 parsecs with a thickness 1,000 to 2,000 parsecs, but with a spheroidal enlargement at the centre 5,000 parsecs or more in thickness. There are however scattered high velocity stars and the globular clusters extending beyond these boundaries 5,000 to 10,000 parsecs and a thin stratum of absorbing material some 500 parsecs in thickness is interspersed among the stars near the central plane. While these conclusions have been fairly definitely stated, the proposed model must be considered only as a preliminary attempt at the solution of this difficult but fundamental astronomical problem. In view of the changes that have occurred in our conceptions of the Galaxy during the past twenty years, it would be very rash to predict even approximate finality. The present concept however has a certain unity and probability and it can only be hoped that it makes a useful introduction to more complete knowledge.

A LUNAR HALO IN ALBERTA

By H. B. Collier

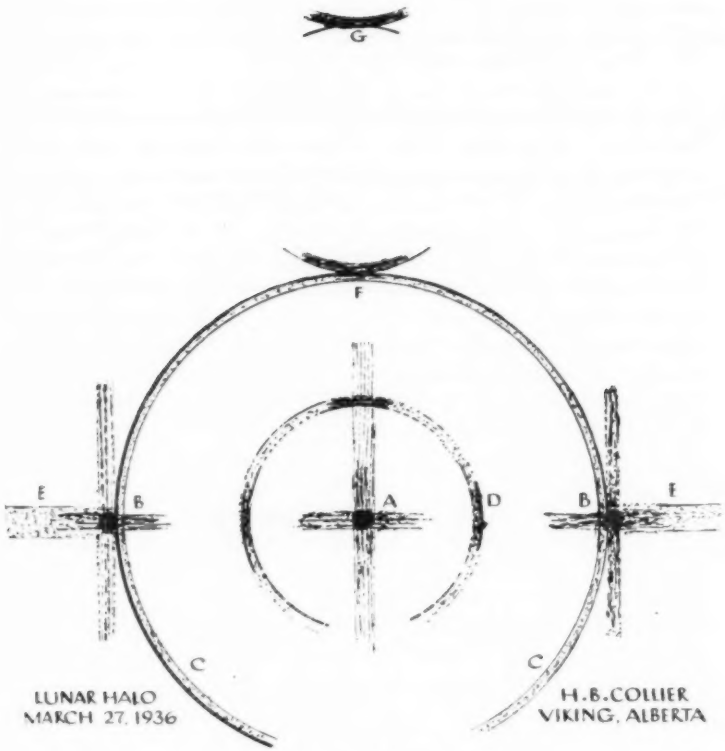
ON Friday evening, March 27th, 1936, a most remarkable lunar halo appeared at Viking, Alberta. A light breeze from the northwest filled the atmosphere with fine ice or snow crystals. There were no clouds. The moon was five days old, and shining brightly. At 8 p.m. there were indications of a halo, but the full picture was not presented until 10 p.m.

I hesitate to record my observations, for they may appear to be at variance with the text of the booklet issued by the Department of Marine regarding halos. However, I welcome correction if the laws of refraction will not permit the figures my measurements determine. You will observe that the paraselenae are shown on the circle of 46 degrees, and not on the 22-degree circle. They were so bright as to rival the moon. I measured the distance between the mock moons and found this to be approximately 46 degrees.

A sketch is such a hopeless thing when trying to depict light. It is like using the devil to picture heaven, when one takes india ink to represent a halo. You will have to use a lot of imagination accordingly.

Here it is just before Easter, and in the sky appear three great white crosses, side by side, the central one the most brilliant and glorious. Around the whole sky parallel to the horizon is a pale white band about 3 degrees in width. About the central cross is a thin white circle with glowing spots at top and sides. And outside of this again is another great circle, double the brightness of the other. At the points of contact with the two outer crosses the brilliancy is enhanced by coour, an indigo-blue. At the upper edge a short, bright arc appears, and another about 22 degrees higher in the sky. The beauty of the whole display is beyond words. If a little religious frenzy were mixed with the phenomena, remarkable conclusions might result. But cold science holds us to the laws of refraction, without detracting from the magnificence of the spectacle.

Students of meteorological phenomena may be interested in the



Explanation of diagram.

A. The moon with a great cross upon it.

B,B. Mock-moons or paraselenae, each with a great white cross, and tinged with indigo-blue on the inside.

C,C. The ring of 46 degrees, diameter.

D. The ring of 22 degrees.

E. The mock-sun ring, encircling the horizon and parallel to the earth.

F, and G. Brilliant arcs of white light.

fact that this display was the forerunner of a storm, wind increasing to 20 miles and temperature dropping to about zero with snowflurries. Yet 35 hours after the moon halo, with the wind still going at least 15 miles, a sun halo appeared on the 29th. The parhelia were of flaming red-orange, and located also on the ring of 46 degrees. The mock-sun band appeared dimly, yet extended for over three quarters of the horizon. Upon it were clearly seen the mock suns of about 90 degrees. These had no colour. The most remarkable feature of this sun halo was the prismatic arc, appearing about 45 degrees above the sun (almost overhead). This inverted arc extended for about 20 degrees, displaying brilliantly about half of the rainbow colours. The circle of 46 degrees was just faintly visible.

EASTERN STANDARD TIME*

A thing I hate, above all else, is Eastern Standard Time.
That's probably what prompted me to couch my thoughts in rhyme.
I must confess, I like it less, the more I hear it spoken.
I've changed my watch so blinking much, no wonder it is broken.
Perhaps it's me; I still can't see, despite their system, just why we
In Winnipeg and West should be subjected to such trickery. . . .
If East and West must disagree, it isn't right, it seems to me
To force us folks on thee prairee to shape our lives by E.S.T.

The other night, I'll have you know, while sitting by my radio
I heard the ringing voice of some bright bloke
Who thus to me, and all his listeners spoke:
"Ladies and gentlemen listening in on Western lines tonight
Will hear the following programs, if their sets are working right. . . .
At two A.M., da da da da da da da da da da,
At two-fifteen A.M. da da da da da da da da,
At three A.M. the Traill Ghost-walker tells of ghosts and crime. . . .
All times given, need I say, are Eastern Standard Time."

Now being a lad with a weakness for ghosts, and a passionate craving for thrills,
I waded through hours of "Gentleman Jim", "Wis and Jeanie", and many more pills,
Then setting my time-piece two hours ahead, I started to read magazines—
Long stories, short stories, articles, poems, and ads about washing machines.
I read, and I re-read, with unflagging patience, until I could scarcely see. . . .
Till at last, almost dead, I glanced at my watch; it was roughly four minutes past three.
I reached for the dial, and turned it on loud, to catch all this "ghost-walking" crew. . . .
But they weren't to be found . . . I tried all around, and George and his girl-friend did too.
All we could get on our six-year-old set was a gentleman singing "boo-boo",
Then a kind of "who's who", and a night-club revue, and the Three Little Middies in Blue.
I looked in the paper, at the top of page three, with a view to obtaining the score—
I found that the Ghost-walker's play had been finished, oh, fully an hour before.

I hope, some day, in Ottawa
M.P.'s will make it statute law
That time is time, in every clime from England to Japan,
Proclaiming there is just one time
(And that not Eastern Standard Time):
The MEANTIME does, as is, and was, since ever time began.

*A rhyme broadcast by "Gentleman Jim" from Winnipeg over the Canadian Radio Commission network.—*Editor.*

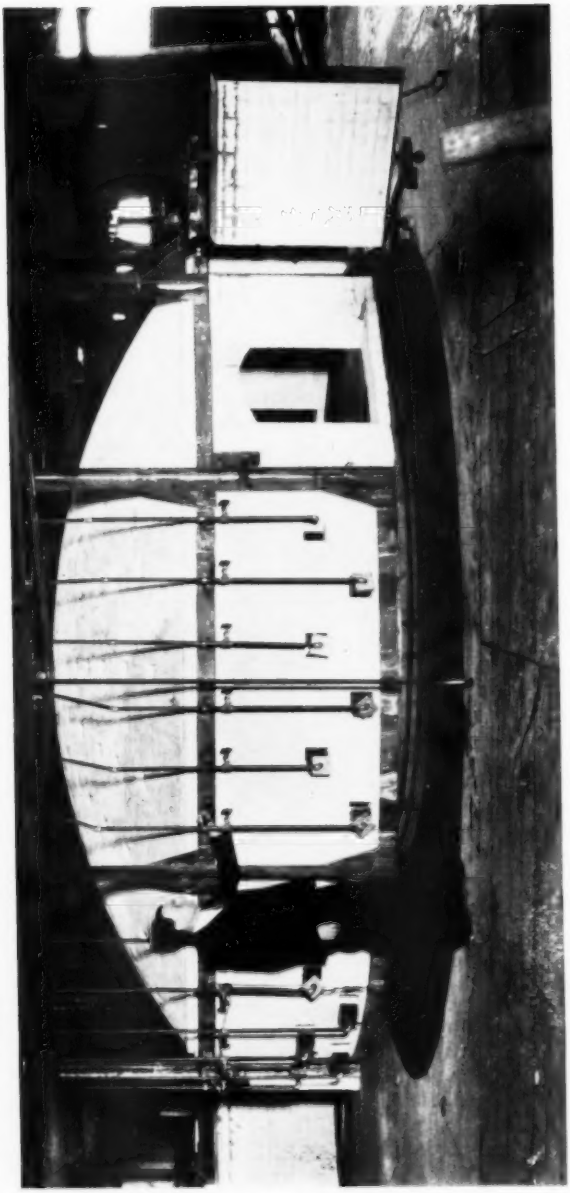


Photo by Stevens.

Dr. G. V. McCauley beside the bee-hive cover for the mould of the 200-inch disc.

PLATE XVI

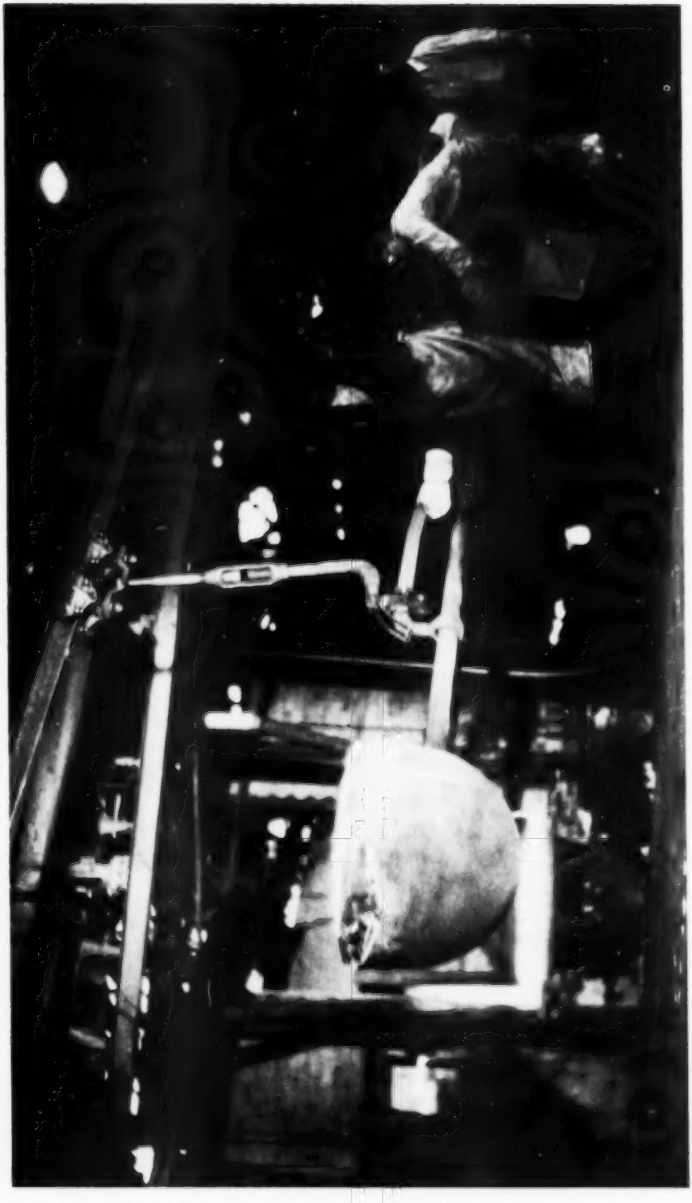


Photo by Stevens.

Removing a ladle of molten glass from the furnace. It was then run on the trolley over to the mould.

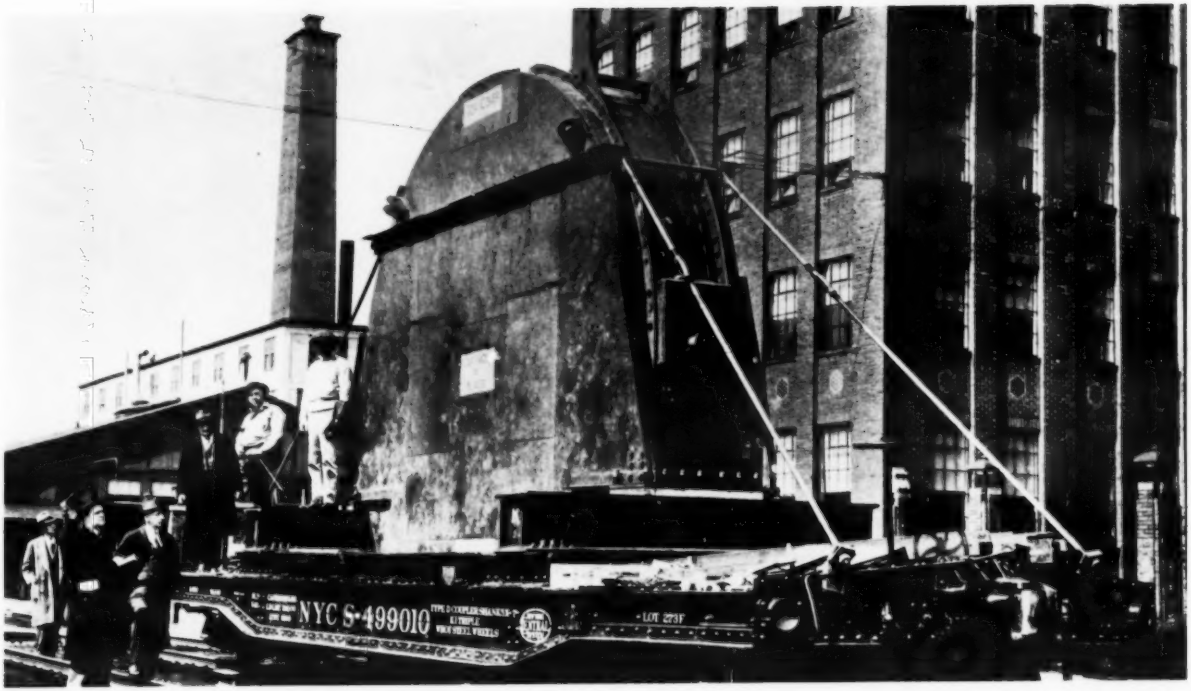
Photo by Stevens.

The ladle of molten glass has been pushed through the door of the bee-hive and its contents are being poured into the mould.

The completed disc, with Dr. McCauley (left) and Dr. Hostetter standing on it.

Miller's Photo Service.

A final step in the loading of the 200-inch disc at Corning. The steel crate containing the disc rests on steel girders across the steel flat-car and extends down through a well-hole until the bottom of the crate is only 5½ inches above the tops of the rails.



Miller's Photo Service.

The 200-inch disc in its steel crate on its special railroad car. At the rear, the Corning Glass Works. The square tower in the background is not a chimney, but a 12-story structure used for drawing tubing for clinical thermometers.

Miller's Photo Service.

The special train on its way from Corning, N.Y., to Pasadena, Cal. It travelled in daylight at a speed not exceeding 25 miles per hour.

THE 200-INCH TELESCOPE EYE*

By O. A. Gage

(With Plates XV-XXI)

HOW much further into space will the world's greatest telescope eye be able to see? Why is the telescope being made? Why was the 200-inch disc made of glass? How far has the work progressed at this date? When will the most remarkable telescope the world has even known be ready to give our earth its biggest look out into space?

The 200-inch telescope disc, which was poured at the Corning Glass Works, at Corning, New York, December 2, 1934, is part of a project for which the total appropriation is $6,000,000. The size of the enterprise and the results which it will achieve are so thrilling that it will be years before they are generally appreciated.

Of course, the ultimate thrill will be in looking into the great instrument to see what man has never seen before, and this must necessarily be the privilege of a small group of America's most distinguished astronomers. The 200-inch project has been in progress for several years, and it is estimated that the telescope will be completed by July, 1939. The new telescope will be twice the size of the present largest in the world, which is located at the Mount Wilson Observatory in California. Incidentally, America is a long step ahead in holding the record for the largest telescopes. The 200-inch telescope disc will collect four times as much light as the Mount Wilson instrument. It will see three times further into space. It will see a volume twenty-seven times as great. Photographs of star images will be made ten times faster. Astronomical authorities, some of them closely concerned with this project, have said that there will be no emphasis on magnification, no inroads on the inhabitants of Mars.

* This is a radio address delivered on April 17, 1936, over Station WEAF and the Red Network, under the sponsorship of the New York Museum of Science and Industry, by Dr. O. A. Gage, Chief of the Aviation and Optical Division of the Corning Glass Works. Dr. Gage was introduced by Mr. James S. Andrews, President of the Metropolitan Astronomical Society, which is a regional branch of the American Amateur Astronomical Association, a national organization, with headquarters in Milwaukee, Wisconsin.—*Editor.*

Magnification is really not important. According to the astronomers, "greater light concentration from afar is our greatest need".

Believe it or not, the 200-inch telescope lens as some people call it, is not a lens at all. It is a reflecting mirror. Roughly speaking, there are two kinds of telescopes with which man looks at the heavens. First there is the kind with which you are more familiar—the spy-glass type. In this, lenses are used. The observer looks into an eyepiece at one end, and sees right out through the other. A series of lenses enables him to observe a magnified image of a distant planet. Lenses, as everyone knows, are pieces of fine quality glass which are so ground that they change the direction of light rays, or bring them to a focus.

The other class of telescope is distinguished by the fact that you don't look in one end and see out through the other. The point at which you observe the star image is on the side and at right angles to the long tube, or otherwise, depending on construction. In this type of reflecting telescope the light rays are gathered by a concave mirror at the bottom of the shaft, the effect being something as if you took the reflector out of your automobile headlight and put it in the bottom of a long tube of equal diameter. The largest telescopes in the world are always made on the reflector plan.

You will understand that the 200-inch telescope is very large when I tell you that the glass disc or "eye" weighs 40,000 pounds. The crate in which the disc has just been shipped from Corning to California weighed 30,000 pounds. The telescope tube will be 57 feet long, and 22 feet wide at the center and will weigh 150,000 pounds. The supporting yoke in which the tube of the telescope will swing is 66 feet long, 46 feet wide, and weighs 600,000 pounds. It will take all of the time between now and 1939 to complete the metal nerves and muscles which will be required to control the eye as it turns to take in the heavens of the northern hemisphere.

Where is the telescope going to be located? Well, first of all, if you were making astronomical observations in your own community you would do it on clear nights. In some communities in the United States the number of clear nights and days per year is relatively small. Then too, the atmosphere near industrial centers is seldom clear. The night glare of city lights is another objection. Consider-

ing all of these factors, the world's largest telescope is to be located on an isolated mountain top in southern California. Its elevation, however, is only a little more than 6,000 feet. This mountain, which is known as Palomar, is 85 miles southeast of Pasadena and 50 miles north of San Diego. Contrary to popular misconception, the new telescope is not going to be located on Mount Wilson. It is being designed to supplement, rather than to duplicate existing apparatus, but the astronomers on Mount Wilson have been most active in its development and they will have every opportunity to use it. Since the inception of the plan for a 200-inch telescope the greatest problem has been to produce its eye, that is, the reflecting mirror. Glass is used because it is the only material available at the present time which is sufficiently free from internal stresses to enable it to be accurately ground and polished. For smaller mirrors certain metallic alloys have been used, but the optical surface made on such an alloy is reduced in efficiency by tarnishing. In order to restore such a surface the mirror must be refigured at a cost of months or years of time. In the case of a glass mirror the reflection of light rays is accomplished by a thin film of silver or aluminum deposited on the top surface, and it is a simple matter to dissolve off the old surface and deposit a new one. Low expansion during changes of temperature is a characteristic of the glass which was used and this is also an advantage. For the 200-inch telescope disc it is expected that the surface will be an aluminum deposit and that this will not oxidize as rapidly as silver, and will offer increased reflection.

America responds to results and is fascinated by possibilities in engineering, but the way, the means, and the mechanisms in the background are seldom revealed except to a small group. Tonight we shall get an inside look into the problem of producing a single solid piece of glass, weighing 20 tons, the idea being, of course, that it must be produced so as to have a minimum amount of internal strain.

On the dawn of a winter day, December 2, 1934, Corning, New York, a city of 16,000 in south central New York State, was tense with expectation about the vast experiment which was going to take place. At 7.17 on that eventful winter morning the ladle crew drew out the first ladleful of incandescent white hot molten glass. It was hot! 2,800 degrees Fahrenheit. One hundred and four ladles were

dipped and poured at the rate of one every four minutes. The last ladle was emptied at 2.10 p.m. (Plates XV-XVII).

Near midnight the great mould with its white hot cargo was lowered from the beehive oven on a 60-ton locomotive hoist. Then it was moved into the big electric annealer.

After the disc entered the annealer and for almost a year, electrical detectives in the form of a squad of robots were gradually lowering its temperature to room conditions. When the glass was placed in the annealer it was red hot. When it was removed on December 8, 1935, it was a great crystal clear solid like a round frozen pool the size of a circus ring. (Plate XVIII).

Corning had made a series of discs, starting with one which was thirty inches in diameter, including the discs for the Toronto, Texas, Harvard, and Michigan observatories, and even a 120-inch disc which is to be used only for testing the 200-inch disc. But when it came to transporting a 17-foot giant millstone of the gods from Corning to California there was the problem of tunnels and bridges, in other words, clearances. A feat which will be historic in American railroading began March 26th and ended fifteen days later on April 10th of the present year. A special train carried the disc by rail on a special underslung railroad car. It travelled at twenty-five miles an hour and had moved forward only by daylight. Every part of the route had been calculated in advance. The New York Central; Big Four; the Chicago, Burlington & Quincy; and the Atchison, Topeka & Santa Fe took turns. There were a few tight squeezes. Sometimes the clearance was as low as five inches. (Plates XIX-XXI). Now safely in California, the disc enters upon a three-year grinding period.

Why does it take so long to grind? Well, to hollow it out spherically takes a comparatively short time, but the finer polishing which gives it a parabolic shape can be undertaken only for very short periods because the polishing heats up the surface of the disc. If it is polished for a half hour or an hour it then waits perhaps a full day before tests can be made and another little area can be brought into line.

The picture of scientists toiling year after year, nerfecting a great optical instrument to extend the vision of man, is strangely in con-

trast with the trend toward destruction now brought to emphasis in so many parts of the world. "Things to Come" is the name of a motion picture which has just opened tonight in New York and is to be released shortly throughout the United States. In this film the same contrast is poignantly pictured. Mr. H. G. Wells, the author, points to the year 2036 as the time when mankind, by a great moral and intellectual effort will have solved the main economic and social perplexities that destroy us today. Evolving after gigantic wars we will live upon a cleansed and beautiful countryside or in great half-subterranean cities flooded by sweet and cleansed air. At a high point in every town there will be an observatory so that man, through perfected materials and instruments, may lift up his mind and heart to contemplate the night's great dome of stars.

Our present-day feats of engineering and science are no more interesting than the men behind them. The whole plan of the 200-inch telescope disc and the incentive for its accomplishment is primarily due to the vision of one man, Dr. George Ellery Hale, distinguished astronomer and Chairman of the Observatory Council, which is in charge of the project. Supervising the construction of the telescope is Captain Clyde S. McDowell of the United States Navy. He is loaned to California Institute of Technology for this project. Strange to say, the mounting and sighting of the biggest naval guns offers the most analogous problem, and in the mechanism of these and in the handling of their great tonnage he is an expert.

At the Corning Glass Works an interesting group of men collaborated. In the words of Amory Houghton, the president, "Our men have co-operated in carrying through a vast experiment, the significance of which can be judged better in retrospect." Dr. E. C. Sullivan and Dr. W. C. Taylor, famous for their development of Pyrex brand low-expansion glasses, say modestly, "Our experience in the field of these glasses has predicated our willingness to undertake the construction of the world's largest piece of glass. Dr. J. T. Littleton, Chief Physicist, whose knowledge of technical problems in glass is encyclopedic, contributed his share. Dr. J. C. Hostetter is Corning's Director of Development and Research. He directs the activities of a whole building full of research chemists, physicists, and engineers. One of the scientists in Doctor Hostetter's division is Dr. George V.

McCauley, now known as Physicist in Charge of Disc Making. To him Doctor Hostetter gave the assignment of developing and carrying out the making of the disc. All hands at Corning point to Doctor McCauley as the man who should be happy now.

Dr. George Vest McCauley used to be a teacher in physics before he entered upon his long term of years as a glass technologist. There are a number of adjectives which define him as the greatest maker of the largest eyes for the world. He is studious, observing, meticulous, sympathetic, conservative and courageous. Essentially he is a man of power without showing it by any sound. He is so unassuming that the task of handling squads of workmen and staying awake day and night on the pouring floor in the heat of the fiery furnaces has no more effect than the laboratory or the drafting board. These things can no more disturb him with personal feelings of satisfaction than they could depress him with feelings of doubt.

How significant this pouring is to be rests with others to evaluate. When we consider that it is to give the earth an original and so far longest look into the seemingly infinite distances of the total universe —at least as far as one billion, two hundred million light years—it may be more significant from the universal viewpoint than anything which has been confined in its significance to the earth itself. It may precede in its effect on humanity the total activity and result of the World War and of all dynasties.

BEYOND THE STRATOSPHERE: CAN MAN TRAVEL TO THE STARS?

By Wm. Gifford Hale

EVER since man turned his gaze upward to the stars his imagination has been enchained by the fancy that some time, somehow, he would be able to travel to those glittering orbs; and fiction writers galore have played with the idea. Lucian, Cyrano de Bergerac, and Dean Swift led the way, Gulliver's travels to Laputa picturing the visit to another world, and, oddly enough, forecasting with uncanny accuracy the facts about the then unknown satellites of Mars.

Jules Verne, was the first real pioneer of space travel, however, in his classic *From the Earth to the Moon*; and the more one studies this book the more one wonders at the fine way in which he combines the thrills of space travel with the most accurate of facts. His machinery for projecting his adventurers across the gulf of space was the only method then imagined by men,—the cannon ball,—and that is the most improbable and unpractical thing in his book. The adroit way in which he avoids the difficulty of return projection by making earth's "second moon" divert their projectile, and so bringing them back to earth on the same powerful impetus that started them off, is a sample of his clever handling of problems hitherto never attacked by any fiction writer, and his *Off on a Comet*, gives a masterly description of a tour through the solar system,—a good introduction to the wonders of the heavens.

Next came Edwin Pallander, in or about the early nineties, who boldly took up the weird possibilities of the gyroscope as a means of travel in space away from the earth. His book, *Across the Zodiac*, employs the resistance offered by a gyroscope to transverse motion as his motive power, for instead of moving in space, he makes his gyroscope hold him still while the rest of the planets move on their way, and so he manoeuvers his ship through the solar system in a series of the most enthralling adventures and encounters with the marvels of the heavens. His descriptive powers are of the best, and

he makes a worthy advance on Verne's ideas of the mechanics of celestial travel.

Wells comes next, with his *First Men in the Moon*, using as his motive power the principle of the neutralization of gravity by coating his machine with a new compound which shuts off the pull of the earth; and the humorous touch with which he introduces the first unintentional use of the new power is a classic bit of description. Nowhere in this type of fiction has finer descriptive power been shown than in his picture of sunrise on the moon, and the first signs of life on that too-readily-supposed-to-be-dead world. Indeed the bits of physical lunar science given by him are both clever and surprisingly accurate. The idea of life beneath the moon's surface, the ever-blowing winds of the interior caves, the central sea, the idea of the frozen atmosphere in the craters, and the life there, all agree most finely with latest ideas of those astronomers who are not afraid to use their wits in piecing together the evidences of conditions and life on the rolling orbs of space.

It is well worthy of note here to mention an anonymous work which anticipated Wells' idea of gravity neutralization, though probably unknown to that talented popularizer of science in fiction. This is *The History of a Voyage to the Moon*, supposed to have been shot back to earth from a lunar volcano. It was published by Lockwood and Co., of London, in 1864. The tellers of the story while travelling in western America, discover a native earth, which when mixed with water rises from the ground by virtue of having so attained a condition of neutralized gravity. It is a curious instance of how ideas are foreshadowed, but the rest of the story is not so impressive as Wells' nor anywhere near so accurate in scientific fact.

The Rocket Idea

Now comes Professor Goddard, of Clark University, with the most practical idea of all, the rocket propulsion. Everyone knows how a rocket propels itself by the recoil from its speedily-ejected gases, but Goddard certainly deserves all possible credit for his application of the idea to interplanetary travel, and it is one of those revolutionary ideas that every now and then take the world by storm, by virtue of their intense practicality. The weak point of all space

travel apparatus was the terrific shock of starting. Verne suggested water cushion, a hopelessly inadequate thing, for one has to overcome the physiological effects of a starting shock of seven miles a second to get free of the earth's attraction. The rocket, by its possible gradual acceleration through the discharge of successive impulses, provides a way out of our puzzle. At first one naturally thinks of separate successive discharges, but a much better way would seem to be a continuous acceleration without gaps in the process, as probably kinder to the bodily functions of the travellers.

Air Resistance

Now our very first trouble is the resistance due to friction of the air, with its concomitant heating of the projectile, for here we should suffer a serious subtraction from our initial impulse. Let us then dodge half of this obstacle by establishing our firing station on the highest mountain available. We could certainly obviate half of this air resistance by starting, say, at an elevation of two or three miles, a perfectly feasible proposition. However, let us suppose all preliminary difficulties overcome, and the way clear for the start. The shape of our vessel might not matter so much in outside space, where no air resistance would be met, but the general idea of Verne's projectile would probably be as good as any, as providing a body that could be depended upon to keep a definite direction both at starting and landing. For remember how Wells' sphere rolled over and over on the moon, certainly an unpleasant way of landing, as well as undignified, if by chance anyone was there to see! Our projectile must be armoured against the sudden heating of its outer surface as we make our first dash through the air.

All ready for the start then! What are the chances of carrying through our daring enterprise to success? Hitherto our troubles are all connected with the start; now we must concern ourselves with the perils of the way. Let us take our seats in the great hollow projectile that is destined to make the first voyage to another world, and in fancy tackle these problems one by one, to see if the genius of man will carry us through. Suppose we have said farewell to the crowds of friends who have assembled to see us off. We enter the car, close and hermetically seal the doors that are not to be re-opened

until we land on another world, where the foot of man has never trod. The rockets are fired and with a mighty bang and flash the car shoots skyward. Jarred almost to pieces and stunned by the terrific blow dealt the base of the car by the first discharge and impulse, we temporarily lose consciousness in the physiological disturbance that assails us, and when we regain it we encounter our next peril, in the sudden heating up of the outer covering of the car. For as charge after charge goes off, our speed increases by leaps and bounds, and the friction so caused by the furious passage of our car through the air, makes the shell so hot that we should incontinently be burned alive unless care has been taken to thickly encase our vehicle with some heat-resisting substance to keep that heat from penetrating to the interior of the car until the cold of space outside has time to make itself felt, and again cool the exterior.

Off the Earth

Now our speed increases to seven miles a second, nearly 500 miles a minute. Indeed it must, to overcome the tremendous backward pull of mother earth, who, it seems, is mighty unwilling to part with any of her children. Below us, as we shoot upwards, is the downward drag of untold millions of tons, in fact, the whole ponderous mass of the world. Suppose our car has been well and truly aimed at the moon, which, being a hundred times nearer than any planet, will surely be our first objective. Then our first minute of space travel has taken us clear above the limits of the atmosphere, and we are at last in the open gulf between the worlds. The colour of the azure sky will in the first few seconds swiftly darken to violet, and then to ebon black, and in a breath myriads of stars will flash into view, while still the sun blazes away with undiminished glare,—in fact it will have a much more deadly dazzle, for now we have only for shield against the ultra-violet and infra-red rays the feeble protection of our window-glass and the few feet of atmosphere inside the car. Here the chemist must have been ready to aid us with some extra protective shield, which we shall suppose supplied by the marvels of modern science. But only look at those stars! Such brilliance and such colours man has never seen before, as the radiant glory of the universe dazzles our startled vision. With all their native

intensity of light and furnace-like incandescence, those countless points of light blaze out in all the hues of the rainbow, a spectacle to make the hardest nature bow in spontaneous adoration. Where the earth-dweller sees hundreds we now see thousands, glittering stars of dazzling white and blue, glowing yellow, clear green, and orange, purple and deep crimson. In beautifully-contrasted colours, as of a jewelled circlet, shines the Northern Crown, and the many star clusters that to earth seem but dim clouds of misty light shine here in outer space with the massed glare of a thousand brilliant points of light, close set in the black velvet canopy of heaven. Overhead the silvery moon is calmly shining, as she advances steadily towards the point where she is to meet us some hours later. At first a quarter of a million miles away, but rapidly nearing us now, under our combined speed of twenty thousand miles an hour.

Our next pressing question is, Can we maintain our speed? Our car is in the position of a stone thrown upward from the ground with the whole earth trying to pull us back and decrease our upward rush. We must cover at least seven-eighths of our journey before that backward pull brings us anywhere near a pause. Roughly speaking, the earth's power over us is 80 times that of the moon, so we shall have to travel 200,000 miles out of the total of 220,000 to reach the point where these two pulls will balance each other. Once past that, we can fall all the rest of the way to the moon, and we shall need more unused rockets to discharge them in order to check the speed of that tremendous fall of 20,000 miles. To make sure, then, that we are travelling fast enough to reach the neutral point, the critical passage of our journey, we must take accurate observations of the distant earth at well-separated intervals, to find out if its apparent size is diminishing as fast as it should do if our speed is properly kept up. Vast, below us looms the great world globe we have left behind us, a dim green disc with the continents and oceans outlined upon it, a spectacle of rainbow beauty when thus viewed from celestial space. There are all the races of humanity, nations at war and at peace, civilizations going and civilizations coming to the birth, wars threatening the progress of humanity, and science struggling to push it onwards. Our observations reassure us as to the maintenance of our upward speed at a safe amount, and we turn our attention to the grand spectacle outside.

A Celestial Barrage

At once another peril of space travel strikes our alarmed senses, as a loud rap sounds on the outside of our vehicle, followed in rapid succession by others. In sharp staccato raps, like those of a rifle barrage, single, double, and quickly repeated shots, rising sometimes to a rattle of musketry, comes the assault of the meteorites of space, determined to do their bit to prevent us from attaining our distant goal. For now we are away from mother earth's leading strings, the protective shield of the atmosphere is withdrawn, and no longer do the "shooting stars" find themselves checked and burnt up by the resisting air that surrounds the world as with a "sure defence" against these "rovers of the sky". Now we are open and bare to their assault, and vicious indeed do we find it. Tiny they certainly are, no bigger on the average than swan-shot, and few indeed as big as a rifle bullet, but their tremendous speed more than makes up for their lack of size and weight. The rate of our car, say ten miles a second, is only a fraction of that of the very slowest of these pot-shots of space, whose average is 30 miles a second, and often more than that. Only when they happen to be going the same way as ourselves, and so overtake us, is their relative speed as low as 20 miles a second, or a thousand miles a minute, or ten times that of a rifle bullet. Imagine then with what force they strike our car. Luckily for us many of them are only brittle bits of stone, which shatter harmlessly into dust with the force of their impact against the outer walls of our projectile, but others are not so innocuous. These are of true ordnance material—no less than nickel-steel—compounded by nature in a warlike mood, in some strange starry foundry of space. Here they come, flying at us through the dark as if aimed with all the vicious intensity of a sniper who shoots to kill. Useless it is to try to dodge them, even if we could steer our car out of their course, for being so tiny they are quite invisible until they actually strike us. The one that hits us this instant ten seconds ago was a hundred miles away, so we just have to trust to the toughness of our walls and take our chance. Ages ago it would not have been so safe as it is today, for then there were plenty of huge rocks flying through space, but now there are hardly any left massive enough to smash our car by their bulk and weight, for the big fellows were all picked up by

the earth aeons since. This old world of ours has been busy cleaning up the solar system for millions of miles around the sun, for a billion years at least. And those other planets too,—Jupiter, Saturn, Mars, Venus, and even little Mercury, are for ever industriously employed "mopping up" these little vagrants of space, and as these worlds all vary their courses around the solar orb every time they encircle him, they plow a fresh furrow every time. So in the course of untold ages the space around the sun has been cleared of all but the flying dust of what was once, in the far-off beginning of things, a dense mass of lumps of stone and metal of all shapes and sizes, from pieces no bigger than your fist to rocky masses as big as a house, and even far above that, to great mountains flying along in space by themselves, unattached to any world and heavy enough to shake this poor old earth in deadly earnest when they finally hit it. They could dig great holes in it as is evidenced by the weird Canyon Diablo in Arizona, where some time in the distant past a meteorite 500 feet across and weighing perhaps a million tons, crashed to earth, and covered the ground for miles around with flying fragments of meteoric "irons", as collectors call them.

Encountering Duplicate Moons

But we, on our moonward trip are thankful that such monsters are few and far between, and hope to escape their too pressing attentions during our ten-hour dash across the quarter-million miles from mother earth to her satellite. What might more seriously interfere with our little jaunt is the possibility of meeting earth's second moon. For it is more than suspected that our world has another satellite beside the great silvery globe we know, that lovers delight to gaze upon. Even its probable distance has been calculated. Not till we have travelled ten thousand miles on our way shall we run any chance of meeting satellite junior, as it might well be called. A small asteroid, or big meteorite, whichever you like to call it, for they both amount to the same thing, it once came, in the course of its too eccentric career around the sun, just a bit too near the earth, and for a wonder was not gathered in to her bosom like the rest, for it very nearly got by when the giant pull of the world roped it in, and swung it round in a circle, which, once started, could in no wise

be any more stopped or changed, and so it became Moon No. 2 of our earth. Anywhere from 10,000 to 20,000 miles out we may come across this little moon, or even several of them, tiny globes when compared to the earth, but big enough and ponderous enough to cause us plenty of trouble. Their approach, however, would not be sudden and unannounced as the small meteorites, for their bulk would render them visible by reflected sunlight while still some thousands of miles away, and so we should be able to dodge their onset and keep clear of their track. Remember how Jules Verne's travellers were diverted from their goal by the too close passage of the second moon, though it did not touch them, but its attractive power pulled them aside from their right direction, and they lacked sufficient steering power to correct the deviation. The modern rocket car will be provided with plenty of side rockets to play the part of rudder to this first "celestial ship". One asks how it is that astronomers have never sighted this extra moon of our. It is because bodies near the earth must move very rapidly to keep from being pulled down to the ground, so they would cross the limited field of view of a telescope like a flash, for they circle the earth every few hours. Five hundred miles a minute is about the least speed they must maintain to keep them safely whirling round the globe, at their distance of ten thousand miles. If they move farther out where the pull of the earth is less powerful, a smaller speed will serve. That is why the moon we know can keep safely away from the earth's great attraction by a speed of only half-a-mile a second, or the trifling pace of 50,000 miles a day, at her mean distance of 240,000 miles. Others suspect a third moon, a million miles away, travelling still more slowly.

Looking Back

Turning our gaze now backward, or downward, at the world we have left behind us, we see a great green globe, half filling the sky. On its immense curving side we see the continent of America stretching from pole to pole, as our eye runs along its sinuous coast line from Alaska to Washington, to California, Mexico, on to Panama, and trending eastward still, we trace the great walled line of the Andes as they stand like an immense barrier to the Pacific

tide and for 5,000 miles rim the greatest ocean in the world. A stately glittering wall of snow-clad peaks and smoking volcanic cones, they range ever southward through Peru and Chili to Patagonia, and past roaring Cape Horn, across the icy waters of the far south, to where a white cap marks the vast Antarctic continent, piled high with ice and snow. Dotted over the blue expanse of the Pacific we see the green coral islands of South Sea romances, and as hour after hour increases our distance from that retreating earth-home of ours, we see Australia and Asia swing into view as the great world spins majestically from west to east. Steadily it recedes as we silently mount higher and ever higher in the heavens toward the moon, shrinking as it goes, until it hangs like an immense green moon in the sky, with the stars shining all round it, in myriad gleaming points of light. And we seem to hang quite motionless in space, for our great speed is absolutely imperceptible by jar or swerve as we fly ever onward across the measureless leagues of the sky. All around us, below, above, on every hand, glitter the uncountable hosts of stars, the majestic heavens, the overaweing creation of God. Here, as never before, comes home to our mind with overpowering force, the Psalmist's thought: "When I consider thy heavens, the work of thine hands, what is man, that Thou art mindful of him, or the son of man, that Thou visitest him?"

The Approach to the Moon

So, after ten hours of wildest thrill and hairbreadth escapes from the rushing projectiles of space, we see at last the silver disc of the moon growing ever nearer and larger among the stars ahead of us, until we reach that critical stage in our journey where earth and moon pull us with exactly equal force: the "neutral point". Now we experience the oddest sensation of losing all sense of weight, for weight is only the expression of the downward pull of the mass of the world under our feet. For hours it has been growing less and less as we soared away from the earth, and we have been conscious of an ever-increasing lightness of body, and ease in movement, as if we were developing wings. Lately it has become so marked that the least stamp of one's foot on the floor has sent us yards into the air, to float down again as light as a feather. The climax comes when

we reach that neutral point and our weight vanishes altogether, as the gravitation of the moon equals that of the distant earth. Then the least involuntary movement sends us floating up in our car, and leaves us suspended in mid-air without the power to come down again, unless we can reach some fixed object on the side of the projectile and pull ourselves down like a toy balloon on a string. If we tried to pour out a glass of wine to drink to the success of our venture it would refuse to leave the bottle, but would stick there as if frozen. Not for long would this disconcerting perfect balance of the forces of nature continue, however, for as our car in its steady flight to the moon passes beyond this weird point, the mastering gravity of the moon asserts itself, and we are gently drawn down to the floor of our car again.

The Heavens Swing Round

Just now, as we look out of our window, the stars that have seemed so still and immovable begin a most dizzying swing over. Slowly and steadily we see the whole heavens glide past our astonished vision in an unceasing procession, until those stars that were over our heads are under our feet, and vice versa. As the weird movement ceases we realize that all that has happened is that our car has turned over, as its heavy base was pulled around by the increasing attractive power of the moon, away from the earth, to which hitherto it had been directed, towards that silvery goal of our journey, which now apparently lies down beneath us, and towards which we are now beginning to fall.

A Fall of 20,000 Miles

And what a fall! Committed now to a fall of 20,000 miles, we are seized with a qualm of fear, like the passengers on a runaway train downhill. Can we, after all, check our downward rush to the moon enough to avoid disaster, or no? A glimpse at our indicator of the number of unused rockets reassures us. There are enough to counteract the falling speed of many miles a second, so we are safe as far as that is concerned, for, be it realized, precisely the same kind of discharge that started us up away from the earth will now serve to check our too speedy approach to the moon. Let us then

breathe freely for awhile, and enjoy to the full such a sight of the moon as never mortal saw before, and one that astronomers by the score would give their ears to see. For there beneath us, viewed through a window in the base of our car, is earth's sister planet and faithful companion of myriad-year journey through celestial spaces. To view the earth we have left so far behind us, we must now look upwards through portholes in the top of our car, and see a small green disc hanging, seemingly immovable in the heavens. If we left the earth when the moon was nearly full, then the old world would appear like a dull dark disc, with a thin crescent of light along one side, like a great new moon. The moon itself, that we are heading for, lies beneath us, with the sun shining down upon it from over our heads.

There, below our fascinated gaze we see such a continental expanse of vast desert plains, rocky peaks, and jagged cliffs, and enormous black pits of unfathomable depth, as earth in her wildest scenes can never equal. For on earth rivers, wind, and rain, combined with crustal upheavals and subsidences, are ever at work, wearing down the mountains, smoothing out the rocky plains, and carrying the debris out to sea, and there spreading it out in level sheets, to form the leaves of the mighty book of earth-history, for future geologists to read. But on the moon no such levelling action ever seems to have taken place, except for landslips on the steep slopes of the craters, and possibly the melting down to a level plain of a rocky expanse by the intense heating caused by the arrival and explosion of some giant meteor of pre-historic times, when such great remnants of the original sun-explosion still careered through the interplanetary spaces of the solar system. Our satellite seems practically destitute of air, insufficient to carry water-vapour to cause rain, so there are no rivers to carry debris to the sea, and no sea to carry it to.

So, all we see beneath us is a wilderness of steeply-piled mountain rings, with here and there a mountain of solid shape, as contrasted with the almost universal ring "craters" which cover most of the lunar surface,—weird, circular pits with their bottoms far below the general surface of the surrounding country. If one were to approach one of these on foot one would have to climb the outer

edge of a curving line of jagged peaks some ten thousands of feet high, and then would find himself looking over into an awful gulf fifteen or twenty thousand feet deep, a great round plain far below, with, in most cases, a smaller mountain, say seven thousand feet high, standing in the centre. Of all sizes, from great cirques of a hundred miles across to little ones no bigger than Vesuvius in Italy, they stud half the moon's surface, like the shell-holes of a battle-field after a fierce bombardment. And in very truth a terrific battle-field it would have been, for any luckless man standing there when these celestial bombshells arrived, plunging down from the sky with ten times the speed, and a hundred times the force of an earthly projectile. But this is another story, the cataclysmic history of our peaceful-looking moon, which will make good telling, perhaps in the future.

Landing on the Moon

Now we have to exercise all our wit to effect a "perfect landing". Nearer we drop to that fearsome rocky surface, and by luck find ourselves descending towards what looks like a sandy plain, and by an extra rocket or two divert our course so as to land upon it. More rockets check our fall, till with no more than a hearty thump we strike the ground and our long flight of a quarter-million miles is over. Lucky, indeed, will the first space-travellers be if fate is so kind to them, for it will be only the beginning of other flights, of greater and ever greater distances, until the technique of inter-planetary travel is mastered, and the worlds of space begin to yield us their secrets and, in the words of Wells, that fearless pioneer of science, "Man shall stand upon the earth as on a footstool, shall laugh and stretch forth his hands to the stars."

(*Note*: Return impetus would be much easier from the moon than starting from the earth, for a fraction of the rocket-power would send us well away from the lunar surface, and once past the neutral point again, our chief concern would be to avoid too rapid a descent. But this again is a matter of mechanics, not of any natural impossibility.)

Astronomical Society,
Seattle, Wash., U.S.A.

ECLIPSES

By A. W. Grant

THE most wonderful phenomenon which can occur in nature, and certainly the one which most directs the thoughts of men to the great Creator of the Universe, is a total eclipse of the sun. To see that wonderful source of heat and light, nay even of life itself for this earth, being gradually shut off from view is a scene which cannot be adequately described in words.

In our day, though still a very impressive occurrence, the cause of the phenomenon is so generally known and understood that it is not viewed with superstition as in earlier times, yet even the great astronomers, who know exactly what is about to happen, stand in reverent awe at the sight. Is it any wonder then that people of uncivilized countries should exhibit such fear, imagining that some demon is devouring the sun?

Prediction of the occurrence of an eclipse was made as early as B.C. 585 by Thales of Miletus. It took place on May 28 of that year, during a battle between the Medes and Lydians. The effect was a complete cessation of hostilities and a lasting peace. Since that time, tireless observation and study of the sky and its phenomena have, in modern times, developed such a degree of accuracy that prediction of solar eclipses is made within a couple of seconds of the actual happening, with a corresponding accuracy of the duration of totality and the area covered by the shadow of the moon.

As regards colouring of the sky at a total eclipse, the scene may be likened to the artificial lighting of a great theatre. The blue sky deepens in colour to an indigo as the eclipse nears totality, and when the last glimmer of the sun disappears with only the corona streamers showing, the earth turns to an ashen colour as if wrapped in a cloak of death. The act is of very short duration with the Master Hand at the switchboard, and as the awe-inspiring scene comes to a close, man laughs and jokes as if some new life were found and his own pygmy show could proceed again undisturbed.

On Christmas day of 1935 there was an eclipse of the sun. As an eclipse it was not of great importance to the astronomical world because it was annular, and also because the path of the shadow of

the moon was over the Antarctic Ocean, passing within 23° of the south pole and traversing no land area. This eclipse was annular because at that time of the year the sun is almost its closest to the earth and appears larger than in July when it is farthest away. The difference, though only some 65″, is considerable when the distance of the sun and moon enters into the calculation. Also on Christmas day the moon was farther away from the earth than its average distance during December and was not big enough to cover the sun. In fact at no time in the month was the moon large enough to cover the sun. There appeared, therefore, an annulus, or ring, of sunlight around the moon when it was directly in front of the sun. In summer, when the sun is farthest away, the moon is ordinarily large enough to cover it completely and a central eclipse is total.

The last previous eclipse was on July 30 of last year. It was a partial solar eclipse and commanded slight attention, because as in all partial eclipses the sun is not darkened sufficiently for one to view either the corona or any other heavenly body close to the sun.

The year 1935 had seven eclipses, the greatest number which can possibly occur in any calendar year. The moon's orbit is inclined to the ecliptic, about 5°9′, and the two points where the moon's orbit and the ecliptic cross are called the nodes. The moon in its revolution crosses the ecliptic twice every 29½ days, and if it happens to become "new" or "full" at or within about 15° of either node we have an eclipse. Under certain conditions we may have a series of three eclipses within 30 days, two partial solar at one node and a total lunar at the other node. The first solar eclipse occurs as the moon approaches one node, and the second occurs 29½ days later, when it has passed the same node. This phenomenon occurred twice in 1935. There were partial eclipses of the sun on January 5, February 3, June 30, and July 30, and total lunar eclipses on January 19, and July 16.

The arc of the moon's orbit where a solar eclipse can occur is almost twice as long as the arc of the same orbit where a lunar eclipse can take place. This is the principal reason why solar eclipses are more numerous than lunar. On the other hand, a lunar eclipse is visible to a whole hemisphere while a solar eclipse is visible, at best, to a strip on the earth's surface not more than 167 miles wide and seldom more than 140 miles.

The *saros* is the interval of 18 y. 11⅓ d. (10⅓ d. if five instead of four leap years are included) after which eclipses are repeated. It was known to the ancient Bayblonians and Chaldeans, and was used by them in the predictions of eclipses. During a saros about 70 eclipses occur, 41 solar (of which 10 are total) and 29 lunar.

Eclipses first appear on the earth at the north or the south pole and at each successive saros travel farther south (or north) and about 120° west till they finally disappear off the earth at the south (or the north) pole. An eclipse of the sun which first appeared at the north pole in A.D. 1295 has been travelling south at each successive saros. On August 10, A.D. 1980, the moon's shadow will have passed south of the equator, and the seventy-eighth or last appearance of this eclipse will occur on September 30, 2665, after which it will disappear into space. An eclipse of the moon, which in the year A.D. 565 covered only half the moon's surface, continued to increase at each successive saros till in A.D. 908 it became total. It remained total at each saros till 1088 and then began to diminish, finally disappearing in A.D. 1413.

The eclipse of July 30, 1935, occurred a saros ago on July 18, 1917. It started 700 miles farther north and, following almost the same south-easterly direction, ended about 200 miles closer to the south pole than in 1917. After a few more saros periods this eclipse will pass off the earth at the south pole.

One saros ago (in 1917) there were seven eclipses in the year, four of the sun and three of the moon. The last previous combination of three and four was in A.D. 1787 and the next one will be in A.D. 1982. A combination of five solar and two lunar, such as we had in 1935, will not occur again till A.D. 2485, the two previous ones being in A.D. 1805 and 1255.

In 3,600 years, from B.C. 1154 to A.D. 2485, a combination of two lunar and five solar eclipses has occurred or will occur only fourteen times, and we who could view such a phenomenon last year were particularly favoured, for our descendants will have to wait 550 years for another such phenomenon. In the same 3,600 years, there have been or will be three lunar and four solar eclipses thirty-three times, and many of those living to-day will see the next one, 47 years hence.

Prediction of eclipses beyond the year A.D. 2485 are not at

present of much interest, and a small variation in the moon's orbit, the cause of which has not yet been definitely determined, may make a slight change in the dates over so long a period.

The year 1935 was the fifth time since B.C. 1145 that seven eclipses have occurred at two successive saros periods, the last previous one being 130 years ago, but no person living to-day nor any of their descendants to the seventh generation will see the next one.

Ottawa, Ont.

REVIEW OF PUBLICATIONS

Through the Telescope, by Edward Arthur Fath. VIII and 220 pages, 6 x 9¼ in., 110 fig. New York, McGraw-Hill, 1936, $2.75.

Ten years ago Professor Fath produced his *Elements of Astronomy*. It was at once successful and has been constantly revised so as to keep it up to date, the third edition being published in 1934.

The present volume is intended for the general reader rather than the student. Dr. Fath has the knack of clear and lively description, and judiciously chooses the subjects which he wishes to present.

Wide interest has been aroused in the discoveries announced by the astronomer and there is a great desire among the people to view with their own eyes in a telescope the objects which are reported to have been found. In general this wish cannot be gratified and our author undertakes to do the next best thing. He describes and illustrates the construction of various astronomical instruments and the manner in which they are used, and then what the visitor will see if he is seated in the observing chair of the astronomer. The book contains numerous pictures of modern instruments and many of the photographs taken with them.

Professor Fath has spent considerable time in study and research at the Lick and Mount Wilson observatories and he takes his readers on visits to these two famous institutions, although he introduces other observatories also. Of course he explains some of the modern ideas, such as the size and distance of the extra-galactic nebulae, the expanding universe, and the development of a spiral galaxy.

The author states that the limit he set for his book was the amount one could read through in an evening. It is true that the story is so well told that the reader will wish to finish the book in a few hours, but he will do well to return to it and read it over many times if he really wishes to obtain and retain a clear picture of the universe.

C. A. C.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

Summer Meteor Observations

It is hoped that all those interested will observe the Perseid meteors this summer. The three best nights for observation will probably be Aug. 10-11, 11-12, 12-13, and the best hours for observation from 10.00 p.m. to 3.00 a.m. Standard Time. The moon is at the last quarter on Aug. 9 which will make the nights immediately following the above three dates better than those just before. A photographic programme will be carried out at the Dunlap Observatory on the three maximum nights and photographic observations from other stations in southern Ontario will be particularly valuable. The writer, as in previous years, will be glad to send instructions and maps to those wishing to make visual observations and will also send instructions to anyone wishing to try meteor photography.

Recent Programmes of Meteor Photography

Two interesting reports concerning direct meteor photography have appeared recently in the *Journal of the British Astronomical Association*. The first is by E. H. Collinson in the January number of this publication (vol. 46, p. 116, 1936). It gives the results of meteor photography carried out in the period 1929 to 1934. Exposures were planned during the epochs of well-marked meteor showers and on all clear, moonless nights during the last five months of each year. This programme was carried out in full during the years 1929, 1930, and 1934, but was considerably curtailed in 1931, 1932, and 1933. The type of lens used most frequently was an Aldis anastigmat of aperture ratio F 3, focal length 6 inches, and field about 1,000 square degrees in area. Other lenses of about the same focal length but with aperture ratios varying from F 2.2 to F 3.5 were also used. In all, 452 plates were exposed for a total exposure-time of 411 hours and 20 meteor photographs were obtained. In 6 of these cases visual observations from a second station were available and real paths were computed. The averages for the 6 meteors give: height of appearance, 119 km.; height of disappearance, 86 km.; path length, 45 km.; and mean magnitude, —1.5.

The second report is by H. H. Waters in the February number of the same *Journal* (vol. 46, p. 152, 1936). Five Dallmeyer portrait lenses were mounted on an equatorial mounting. The focal lengths ranged from 6 to 8 inches and aperture ratios from F 2.2 to F 3.8. Since the definition at the edge of the individual lens fields was poor the five lenses were arranged with the fields overlapping to a considerable extent. The total area of the sky covered in reasonably good definition was about 3,000 square degrees. A rotating shutter driven by a sewing-machine motor was mounted to occult two of the lenses 16 times a second. Exposures with this battery of cameras were made during the maximum nights of the Perseids and Geminids in 1933 and of the Lyrids and Perseids in 1934. Three meteors were photographed in a total exposure-time for the battery of 9.2 hours. In the case of one meteor photograph the rotating sector was not operated because of a high wind, and in the case of the other two it is not noted in the article whether the photographs were obtained with the cameras equipped with the rotating shutter or not.

The Expectation of Success in Meteor Photography

Since quite a number of programmes for meteor photography have been carried out during the last six years it seems worth while to summarize here some of the results so that the prospective meteor photographer will be better able to gauge in advance his chances of success. Obviously, chance plays a much bigger part in meteor photography than in most other fields of astronomical research and yet, in the long run, the number of hours' exposure required for each meteor photograph should average up fairly well. The results for the direct photography of meteors are given in Table I and for the spectrophotography in Table II. Most of the programmes listed have been reported by the writer in either this Journal or in the publications of the Harvard Observatory. The first column in Tables I and II contains the station from which the observations were made and where this is given as Harvard or Toronto it generally includes several co-operating stations. The following columns in order give: the dates of the exposures; the total number of hours exposed; the numbers of meteors photographed (all are included whether sporadic or otherwise); and the number of hours' exposure-time for each

meteor photographed. The last column lists the type of programme: *a* is for programmes where all exposures were made near the dates of the maxima of well-marked showers, *b* where exposures were in general made at the time of showers but where observations were also made on other nights, and *c* where all dates near the major

Table I *Direct Meteor Photography*

Station	Date	Hours Exposed	Meteors Photographed	Hrs. Exp. per Meteor	Type of Programme
Harvard	1929 Nov. 15-17	2.9	1	3	a L
Harvard	1930 " 19-20	2.4	0	—	b L
Harvard	1932 " 14-18	24.5	13	2	a L
Toronto	1933 " 14-16	37.8	4	9	a L
Harvard	1933 " 14-17	34.0	4	8	a L
Toronto	1934 " 14-17	12.2	2	6	a L
Toronto	1935 " 17-18	5.7	2	3	a L
Dwight, Ont.	1931 Aug. 10-13	5.2	1	5	a P
Harvard	1932 " 11-13	6.7	1	7	a P
Toronto	1934 " 10-13	28.4	6	5	a P
Toronto	1935 " 11-13	4.7	1	5	a P
Ensley, Ala. (Alfred Boyles)	1935 " 9-12	5.0	5	1	a P
Toronto	1933 Dec. 11-12	11.6	3	4	a G
Ft. Worth, Tex. (Texas Observers)	1936 Jan. 2- 3	2.0	1	2	a Q
England (H. H. Waters)	1933-1934	9.2	3	3	a P G Ly
Ensley, Ala. (Alfred Boyles)	1933	105.4	5	21	b
Ft. Worth, Tex. (Texas Observers)	1933	82.4	4	21	b
England (E. H. Collinson)	1929-1934	411.	20	21	b
	Totals	791	76		

showers were omitted. *L* stands for Leonids, *P* for Perseids, *G* for Geminids, *Q* for Quadrantids, and *Ly* for Lyrids. The average type of camera used on these programmes was one with an F 4.5 lens of approximately 6-inch focal length and covering a field about 1,200 square degrees. Both slower and faster cameras were used in the

direct photography and faster ones in the spectrophotography, but it was not believed necessary to add these details in this short summary. In general, where a nominally faster lens was used, the field in good definition was somewhat smaller and this offset any advantage gained by the more favourable aperture ratio. It is interesting to note the chance close agreement in rates for the last three programmes listed in Table I.

Table II *Meteor Spectrophotography*

Station	Date	Hours Exposed	Meteors Photographed	Hrs. Exp. per Meteor	Type of Programme
Harvard	1931 Nov. 11-14	16.7	0	—	b L
Harvard	1932 " 14-18	56.9	8	7	a L
Toronto	1933 " 14-17	15.8	0	—	a L
Harvard	1933 " 14-17	86.5	2	43	a L
Toronto	1934 " 14-17	26.9	0	—	a L
Toronto	1935 " 17-18	15.8	1	16	a L
Toronto	1934 Aug. 10-13	50.7	4	13	a P
Harvard	1935 " 10-13	20.3	0	—	a P
Toronto	1935 " 10-13	10.2	0	—	a P
Harvard	1931 Dec. 7-15	84.9	2	42	b G
Toronto	1933 " 11-12	17.8	0	—	a G
Toronto	1934 " 13-14	16.3	1	16	a G
Ft. Worth, Tex. (Texas Observers)	1936 Jan. 2- 3	4.0	1	4	a Q
Ft. Worth, Tex. (Texas Observers)	1933	55.5	2	28	b
Arizona	1932-1933	1351.	5	270	c
	Totals	1829	26		

In Table III will be found the average length of exposure necessary to secure one meteor photograph as deduced from the first two tables. We might state the results briefly thus: In direct meteor photography one photograph is to be expected for every 4 hours' exposure on nights near the Leonid and Perseid maxima, one for every 4 to 8 hours' exposure near the Geminid maximum, one for every 20 hours' exposure on general programmes including the

Table III *Average Exposure Time per Meteor Photographed*

	Programmes	Exposure Time per Meteor Photo.	Type of Programme
Direct Photography	Leonids (1929-1935)	4.5 hrs.	a L
	Perseids (1931-1935)	3.5	a L
	Geminids (1933)	4.	a G
	General (including showers)	21.	b
Spectrophotography	Leonids (1931-1935)	20.	a L
	Perseids (1934-1935)	20.	a P
	Geminids (1931-1934)	40.	a G
	General (not including showers)	270.	c

periods of meteor showers, and one for every 50 hours' exposure on general programmes excluding nights near the maxima of well-known showers. In meteor spectrophotography approximately five times the above exposures are required to secure one photograph. These results will probably hold fairly well from year to year with the exception of the Leonids. It must be remembered that the above programmes cover the last Leonid return and that the number of bright Leonids available for meteor photography will probably be much less during the next 25 years.

P.M.M.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Further Notes on Florida

One of the finest memorials to any person is the Mountain Lake Sanctuary and Singing Tower presented by Edward W. Bok to the people of the United States—and visitors from beyond its borders. This charming place is almost at the geographical centre of Florida. The tower is located on the highest hill in the state, the elevation being given as 324.9 feet above sea level. It is 205 feet high, and is of beautiful design and admirable construction. The combination of coquina stone with pink marble, along with its location among semi-tropical trees and many-coloured flowers, make a perfect picture. Within the tower is a magnificent carillon of 71 bells, comprising four octaves, which give forth peculiarly sweet and soft music in true tones.

On the south face of the tower is a sun dial which attracts the astronomer's attention. On this it is stated that the latitude is 27° 56′ 10″ N., the longitude is 83° 35′ W. and that it has a declination of 4° 20′. A picture card states that "the dial stands vertically at an exact right angle with the surface of the earth", and that "it is tilted towards the east with a declination of 4° 20′." Just what this latter statement means the present writer does not understand, but supposes that the dial is in a vertical plane, but not exactly east-west, and that a perpendicular to it points in a direction 4° 20′ east of south.

The gnomon is a plain gilt rod of rectangular section supported by a bracket in the form of a partially-coiled snake. Around the dial are the signs of the zodiac. Engraved on the marble base of the tower, below the dial, is a curve from which one can read the number of minutes which must be added to the reading of the dial (i.e., the local apparent time) in order to obtain the eastern standard time. The time thus obtained agreed satisfactorily with the present writer's watch on the occasion of his visit.

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A newspaper heading may arrest the attention without conveying the meaning intended. On March 19 the St. Petersburg *Times* had a two-column heading:

SPONGE CITY BELLS TOLL
TRIBUTE TO VENIZELOS

This suggested that certain city bells were being sponged, perhaps to rid them of dust or other matter deposited on them. But it turned out that the town of Tarpon Springs is the centre of extensive sponge fisheries which are controlled by Greeks, that it is called the "Sponge City" and that the bells in its Greek church had tolled for the Greek statesman Venizelos, who had died the day before. Tarpon Springs is an interesting place.

. . . . . .

On making inquiries on March 15, in the face of a lowering sky, as to what we might expect, an experienced Floridian remarked: "Only a fool or a tourist would predict the weather in Florida."

NORTHWARD FROM LAT. 27° 40′ TO LAT. 43° 40′

At the time of starting for home (March 24) the weather was fine and warm, suitable for summer clothes and open car-windows, and such was encountered for several days. On leaving Raleigh, N.C., a light overcoat was agreeable and at Gettysburg, Pa., this was exchanged for a heavier one. Snow fences are often used along the main highways in Ontario, which are not allowed to remain impassable for many hours. Two such fences were seen in position in Maryland, about twenty-five miles north of Washington, D.C., although actual banks of snow were not seen until near Bath, N.Y. (April 2). The general complaint from Florida northward was that the winter had been exceptionally cold, and it still lingered in Ontario. The flooded areas in Pennsylvania were depressing. The height to which the water had risen and the damage it had done were almost unbelievable.

A pleasant, but all-too-short, stop was made in Washington, with its multitude of magnificent buildings and monuments. The Lincoln Memorial—nothing finer—was visited both going and coming. Also a pilgrimage was made to Mount Vernon, where the writer had not been before. From his earliest childhood he was accustomed to see,

hanging on the wall of the living room in the old home, in a frame composed of various kinds of wood, a coloured bird's-eye view of this historic place. The picture was published in 1861 along with Headley's "Life of Washington", which had in an appendix a full account of Mount Vernon, written by B. J. Lossing. The picture now hangs in the writer's home at the David Dunlap Observatory. It was interesting to compare the present-day, well-kept estate with the representation of it in the picture. The marble amphitheatre and the tomb of the Unknown Soldier in the Arlington Cemetery were marvellously impressive.

At the Naval Observatory, located in a 70-acre park within the city limits, it was a great pleasure to meet many friends and to inspect some of the equipment. The very efficient automatic radio time service of the Superintendent, Captain Hellweg, has received high praise from various countries. This is a very modern development. Alongside it fundamental transit circle observations are carried on with the utmost precision. The 26-inch refractor is in continued operation, and one recalls with pleasure the excellent library and the office of the "American Ephemeris" under the direction of Prof. James Robertson, who recalls Canadian forbears.

Promotions at the Dominion Astrophysical Observatory

The retirement of Dr. J. S. Plaskett from the directorship of the Dominion Astrophysical Observatory made necessary some re-adjustments in the staff and the following changes are announced:

W. E. Harper is Director. Dr. Harper has been associated with the Observatory since its inception. He was Assistant Director for some years and latterly Acting Director. An account of his astronomical work was given in this Journal for last September.

J. A. Pearce becomes Assistant Director. Dr. Pearce obtained at the University of Toronto his B.A. in 1920 and his M.A. in 1922 and his Ph.D. from the University of California in 1930. He has carried out many researches, perhaps the most important being his work with Dr. Plaskett on the rotation of the galaxy.

C. S. Beals has been advanced to the position formerly held by Dr. Pearce. Dr. Beals is a graduate of Acadia University and has

studied at Toronto, Yale and Imperial College in London, Eng. By the latter institution he was awarded the Ph.D. degree in 1925 and the D.Sc. degree in 1934.

Robert M. Petrie has been appointed Astronomer of Grade III and Andrew McKellar Astronomer of Grade II. They are both graduates of the University of British Columbia, the former in 1928, the latter in 1930. Dr. Petrie obtained the Ph.D. degree at the University of Michigan in 1932; Dr. McKellar was Whiting Fellow at the University of California and was granted the Ph.D. degree there in 1933.

The present writer wishes these able men continued and abundant success.

C. A. C.

SUPPOSED ERROR IN THE 1936 *HANDBOOK*.

In the last issue of the JOURNAL (p. 147) attention was drawn to what seemed to be an error in the HANDBOOK for 1936. It referred to the star Ross 248, the last but one in the table on page 64. It now appears that by taking into account the colour index mentioned in the *Note* at the foot of the page, the values for the absolute magnitude and the luminosity given in the table for this star are obtained. It may be stated, however, that while Wolf 359 and Ross 248 are mentioned in the heading as intrinsically the faintest stars known, an examination of the table shows that Prox. Cen. and alpha CMiB should be joined to them as in the same class of intrinsic faintness.—EDITOR.

Error in Dr. Hodgson's Article
On page 117, line 16, "down" should read "up".

MEETINGS OF THE SOCIETY

AT EDMONTON

January 9, 1936—Dr. A. J. Cook, of the Department of Mathematics in the University, read a paper on "The Evolution of the Solar System". After dealing with some primitive ideas of cosmogony he described the solar system as it is known to us today and discussed the two main theories of its formation —the nebular hypothesis of Laplace and the planetesimal theory of Chamberlin and Moulton. He pointed out that the former cannot be reconciled with some of the facts and must definitely be abandoned. The second, although more satisfactory, is still quantitatively unsound and needs considerable modification. The speaker briefly mentioned some other modern views but concluded by pointing out that the problem of the evolution of the solar system remains unsolved.

February 13, 1936— Mr. J. G. Taylor presented a review of the late Dr. E. B. Frost's book "An Astronomer's Life". From this review one realized that Dr. Frost was not merely a gifted and capable astronomer who did much important work in astrophysics and stellar astronomy and was able even though blind to act as Director of a great observatory, but was also the possessor of a vivid humorous charming personality. Dr. Campbell contributed some personal impressions of Dr. and Mrs. Frost, obtained during a summer's residence at the observatory at Williams' Bay.

March 12, 1936—A special meeting was arranged on the occasion of the presentation by the Edmonton Centre to the University of Alberta of a set of ten transparencies of astronomical subjects. The photographs were obtained from Yerkes and Mount Wilson Observatories and are uniformly 11″ by 14″ upright. The University in accepting the gift agreed to bear the expense of installation and lighting, and the transparencies are now permanently mounted in a conspicuous position in the Arts Building, where they may be seen by large numbers of students and others as well as by the members of the Centre. At the meeting Dr. J. W. Campbell described the photographs and the reasons for the selection made, Mr. F. S. Simpson made the formal presentation, and Dr. R. C. Wallace, President of the University, accepted them on the University's behalf. A summary of Dr. Campbell's address follows:

What are the things of value that a Centre of the Royal Astronomical Society of Canada can offer to its lay members who lack scientific training or whose scientific training is only elementary? This question is sometimes asked, and one answer is assistance in becoming familiar with the sky. "A thing of beauty is a joy for ever" and there are few who would deny the beauty of a clear starlit sky.

But while one can enjoy the beauty of the sky without knowing the constellations, undoubtedly the ability to recognize and identify them will greatly enhance one's pleasure. The sight of Orion in the fall for the first time after

several months is always a source of pleasure, and he who is out in a clear morning in August before the dawn and sees Orion in the eastern sky experiences a thrill such as he would get from meeting a well-known friend in a strange place. It would be difficult to conceive of a person who is familiar with the stars being out alone on a clear starlight night and feeling wholly lonely.

Also, besides the beauty of the sky to the unaided eye, there is the wonder of the structure which the telescope reveals. It is a commonplace that the distances and dimensions are so great that the numbers expressing them fail to convey meaning, but sometimes a particularly vivid phrase or illustration will strike the imagination with peculiar force. It was with the idea of helping members and other to form a picture of the universe about us that the transparencies were obtained. As the explanatory notes mounted below the photographs say, "If we had super-eyes with which to explore space what should we see? It is the purpose of this set of views to help to describe some cardinal features of what would be revealed."

The series of plates is as follows:

1. The Sun, with spots.
2. A solar prominence, with disk representing the Earth to scale.
3. Milky Way in Cygnus with N.A. Nebula, small scale.
4. North American Nebula, large scale.
5. Milky Way in Ophiuchus, with S-nebula, small scale.
6. S-Nebula, large scale.
7. Great Star Cloud in Scutum.
8. Great Andromeda Nebula and M 33, small scale.
9. Great Andromeda Nebula, large scale.
10. Cluster of Nebulae in Corona.

The first two show some features of the nearest star, our Sun, and the gigantic proportions of the sun-spots and prominences. The next five are sample views of the stars about us. Every dot on each of these plates represents a run such as ours—many of them larger, many brighter, many hotter. The stars about us, thousands of millions in number, are spread in a region shaped something like a watch. We are somewhere near the centre of the aggregation and when we look at the Milky Way we are looking towards the edge of the "watch".

Plates 4 and 6 show parts of 3 and 5 under higher magnification and are intended to indicate how the sky would look if we could examine it in more detail and with more powerful eyes. The explanatory notes contain statements in terms of the Moon of the size of the region of sky which is covered by each plate.

Our "watch" is so large that it takes light, which travels at 186,000 miles a second, about 40,000 years to cross it from edge to edge and it is about 5,000 light-years thick.

On plate 8 there are two objects of another kind. The two fuzzy patches

are separate stellar systems comparable to the galaxy which forms our Milky Way, and plate 9 is an enlarged view of one of them, the Great Nebula in Andromeda.

This photograph is perhaps the most impressive and arresting view in the whole realm of astronomy. One is struck by the beauty of its proportions, symmetry and detail, and when in addition one realizes that he is looking at an aggregation of thousands of millions of suns—seeing a sight such as our galaxy would resemble if we were sufficiently far away from it—well, he can only stand and look! Light from the Great Andromeda Nebula takes 900,000 years to reach us. "Forty centuries look down upon us from yon pyramid's grey head," said Napoleon to his troops in Egypt, and yet the light which made this photograph had completed more than 99 per cent of its journey towards us centuries before the Egyptian pyramids were built.

Plate 10 shows a group or cluster of other stellar systems. There are hundreds of thousands of these "island universes" known at the present time. They vary in appearance and form and they are distributed at enormous distances. The cluster on plate 10 is at an average estimated distance of 120 million light years.

It is hoped that this series of views will be instructive not only to the members of our Centre but also to all others who, when passing, may have time to pause and examine and reflect. Puzzling questions will doubtless arise. Thus the energy radiated from our sun is sufficient to melt a layer of ice a mile thick over its surface in about two hours. Think then of all the energy that is being radiated by all these billions of suns in all these separate systems of stars. Whence does it come and whither does it go? The meaning of it all remains unanswered, but perhaps one maay get from these views some added sense of the vastness of things as they are.

AT TORONTO

March 3, 1936—The regular meeting of the section was held in the McLennan Laboratory, University of Toronto, with Mr. J. R. Collins in the chair.

The minutes of the last regular meeting were read and adopted. The eleven persons nominated at the last meeting were elected to membership. (See p. 149).

The paper of the evening, "Applied Spectroscopy", was given by Dr. H. J. C. Ireton, of the Department of Physics, University of Toronto. Dr. Ireton traced the development of spectroscopy from its earliest beginnings to its applications in modern industry. As a background, he described the various kinds of spectra, continous, line and band, dwelling longest on line spectra. He told how the lines in emission and absorption spectra originate, and pointed out the difference between flame, arc and spark spectra.

In the realm of Chemistry, spectroscopy has given information of new elements. In Astronomy, spectrograms give information regarding the composition, physical conditions and radial velocities of the stars, while the spectroheliograph gives pictures of the sun in various wave-lengths.

The standard of length is now defined spectroscopically—being so many wave-lengths of Cadmium red light, which is very close to being a monochromatic light.

In industry standard powders are made containing 50 different elements, with whose spectrum that of any metal may be compared. This is a very simple method of obtaining a qualitative analysis. Quantitive analyses are also possible spectroscopically and are used in industry to check materials, in pathology to discover the presence of foreign elements and in the detection of crime.

Mr. J. H. Horning showed some slides of the positions of the constellations at the present time of the year. Taking the constellation Orion, he described it in detail, telling the myths and legends connected with it and pointing out the more interesting astronomical objects in the constellation.

Plots of sun spots made by a member of the Society at Weston were on exhibit. These showed the amount of the daily rotation of the sun by plots of the same spot on several successive days.

March 17, 1936—The regular meeting of the Toronto Section was held in the McLennan Laboratory, with Mr. E. J. A. Kennedy in the chair, the chairman, Mr. A. R. Hassard, being absent due to the death of his sister. That a note of sympathy be sent to Mr. Hassard was moved by Mr. Collins and Mr. Duncan.

The paper of the evening, "The Structure of Atomic Nuclei", was presented by Dr. Elizabeth Allin, of the Department of Physics, University of Toronto. Starting with Rutherford's first model, she traced the many changes in the phycisist's view of the composite atom, showing how the fields of radioactivity and artificial disintegration by bombarding particles, told of the more elementary particles composing the atom, namely α particles, electrons, protons, neutrons and positrons. Also, the story of isotopes was outlined, showing the contribution the mass-spectrograph has made in starting to unravel the mystery of the stability of atoms, as yet the big unknown in the field of atomic physics. The present view of an atom is a very small nucleus, composed of neutrons and protons, surrounded by a system of electrons each describing an elliptical orbit. The different elements owe their different weights to the composition of the nucleus, and their chemical properties to the number of extra-nuclear electrons.

Following the lecture a discussion was held, in which the possibility of very dense stars, on the present theory of the atom, was made clear.

Reports of two brilliant meteors, one over the Eastern States and one in Toronto, were made. Dr. P. M. Millman, Dept. of Astronomy, University of Toronto, desires all details of any such phenomena.

F. S. Patterson, *Recorder.*

AT VANCOUVER

February 11, 1936—The 37th regular meeting of the Centre was held in the Science Building of the University of British Columbia at 8.15 p.m., Mr. C. A. McDonald presiding.

Membership in the Vancouver Centre was accepted from Mr. W. H. Tucker and Mr. H. W. Fowler.

The speaker of the evening was Dr. W. E. Harper, M.A., of the Dominion Astrophysical Observatory, his subject was "The Astronomy of the Poets".

The lecturer explained that he aimed to outline the views held regarding the heavenly bodies from Biblical times to the present in so far as such could be gleaned from allusions made to them by the poets of each succeeding age.

The Hebrew conception of the universe was not scientific in the modern sense of the term, but through a contemplation of the heavens they were led into a purer religion and a more perfect poetry than would otherwise have been the case.

Reference was made to observations of the Aurora and meteors in Virgil's day, while Dante's "Divine Comedy" gives us a conception of the universe as held in his day, about 1300 A.D.

Using the astronomy he found among the common people, Shakespeare touched it up with poetic radiance and passed it on. About 300 astronomical references are found in his works.

The old earth-centred universe was still in vogue with the various heavenly bodies, each in its own crystalline shell or sphere, rotating about the earth. The soft gliding of one shell over another produced a heavenly strain of music, the supposed "Music of the spheres" often referred to by the poets.

While using very beautifully the doctrines of astrology to 'point the moral and adorn the tale', passages were quoted to show that Shakespeare recognized the absurdity of the claims of astrologers. In lighter vein the speaker quoted passages from which some might conclude that Shakespeare was familiar with modern radio.

Though Milton, for convenience, used the old earth-centred cosmogony as the basis of his *Paradise Lost*, he intimated in his great poem that his own convictions were that the sun, not the earth, was the centre of our little system.

Many references were made to Tennyson, who symbolized the Victorian era of great achievement in science. Passages were quoted showing his belief in the principles of evolution as applied to the physical universe and to man as well.

The lecturer closed with a brief recital of the extraordinary advances of the present day in the realm of astronomy and felt that there must come a 20th century poet, versed in astronomical lore, and with the poetic ability to weave the facts into a great poem which would voice the spirit of our scientific age.

The lecture was illustrated with suitable lantern slides throughout.

J. W. Moore, *Secretary*.

AT WINNIPEG

January, 1936—Dr. H. P. McPhail spoke to the Centre on "A Theory of the Universe". His address gave rise to considerable discussion and a synopsis of it follows:

All energy is due to motion. The laws of velocity govern the amount of this energy. Matter is confined energy, therefore confined motion. We have motion in a direction and motion of rotation; and these combined. There is no condensible ether, hence no ether condensation waves. In place of the quantum theiry of light, I substitute projectile theory. In place of wave-length I substitute diameter of influence of the penetrating ray-projectile. "Wave frequency" then has no meaning. Light is typical of the pure rays—i.e., motion in a direction only.

In the ascending scale of speed, minuteness, and power of penetration, above the light ray we have the known rays of ultra-violet, x-rays, gamma rays, cosmic rays, magnetic rays, and gravity rays. Magnetic and gravity rays theoretical! Each pure ray has an optimal speed, that of light being 186,330 miles per second. Light from very distant stars and nebulae has not been measured for speed, excepting from inference by means of spectrum bands. These show an apparent slowing of about 1,000 miles per second for each 10,000,000 light years.

The "universe expansion" theory is an unnecessary and illogical explanation for this "shift to the red" phenomenon. The light ray *does slow up*. This pure ray-projectile or photon is not of the nature of matter. It can be instantly deflected without loss of speed or energy. Since all pure photons are travelling at their optimal speed, they all possess optimal energy. They can acquire no energy, hence they can not dispose of any. How then can we account for their loss of speed? In one way only: that is, by having their speed of direction taken up by speed of rotation. From present information in the case of light the entire speed of direction will be absorbed into that of rotation in 1,860,000,000 years. Though I believe the rate of slowing is progressively accelerated, so that the time given is too long. Manifestly now our photon is no longer a photon, but something vastly different. It is a gyroscope with all the tremendous contained energy and stability such a speedy, though minute, gyroscope would have. This I name an *alphon*. Between photon—speed in a direction only; and alphon—speed in rotation only, we have infinite grades of rays with both motions. These are raydons or emanations. They possess both stability and speed.

The gravity ray is the most minute, speediest, and most powerful of all the rays of which we have any perception. Like the cosmic and the magnetic ray, their direction is infinite. They project themselves against every alphon in space. Only when two alphons come close enough to one another to screen some gravity rays from one another, is the force of gravity manifested. Several alphons may be held together to form the nucleus of an atom. This nucleus acts as a field of gravity for one or several speedy but stable raydons. As in the case of the sun and its planets, the speedier ones would occupy the circles nearest the centre. Thus, this atom is made up of the tremendously stable and powerful nucleus together with one or many revolving raydons whose stability is due to their gyroscopic principle, and which are held by the push of gravity and kept apart by their centrifugal force.

Cohesion is also due to gravity, though the interlocking of molecules is a powerful factor in the application of the gravity force. Inertia is due to the gyroscopic principle of the raydons and alphons of the atoms. Recent success in blasting apart of the atom to produce emanation would show that the old electronic theory of atom structure can no longer hold.

Mass gravity is due to the action of the infinitely minute and speedy gravity rays penetrating to and acting on each atom in the mass; but as each mass would screen out some of the rays from the other mass so the greater push would be on the contra-lateral side of the masses. The bodies would be pushed together. When sufficient mass is accumulated, the sum of the gravity rays absorbed and interference from the crowding of the atoms would produce a measure of disintegration of the atoms. Thus heat and light would be formed. Thus the eternal circle is produced of the creation of matter from energy and the production of energy from matter.

Light for the first few million years is practically pure photon, but it is gradually losing some of the qualities of pure radiation and acquiring the nature of emanation. This difference is already noticed in the present telescopes, where it is found the rays from 100,000,000 light years are hard to focus and difficult to identify on the spectrum scale. I predict that at some point between 300 and 500,000,000 light years distant, light will no longer be identifiable as such, but will be definitely of the nature of an emanation, i.e., it will be a raydon. The new 200-inch telescope should verify or disprove my prediction. Electricity, like magnetism, can also be explained on the simple theory of "energy due to velocity".

KATHERINE ST. JOHN, *Secretary.*

AT OTTAWA

April 3, 1936—In a lecture this evening Dr. P. M. Millman, of the Department of Astronomy of the University of Toronto, spoke of a somewhat different conception of the universe from that commonly held. The view expressed, however, was in the nature of only a slight modification to the familiar one which pictures the universe as made up of almost countless numbers of stars which are regarded simply as bodies composed of great glowing masses of gas. It is usual to picture the intervening space as being devoid of matter. Dr. Millman drew attention to the existence of matter in the great expanse between the stars, in other words, to interstellar matter which he termed the debris of space or star dust.

Every shooting star is an indication that the earth, in its hurried journey round the sun, has collided with a tiny particle of star dust which is immediately vaporized in the upper atmosphere. It is estimated that the earth runs into over 25 million of these little particles each day. At certain times in the past shooting stars, or meteors as they are called, have appeared in such numbers that the sky was literally filled with them. Once in a while a meteor is so large that it is not entirely vaporized and then it falls to the ground as a meteorite, a fragmentary piece of iron or stone coming to us from the depths

of space. Meteorites are visible about 60 miles above the surface of the earth, and owing to their fall the earth's mass is increased by about 2,000 tons every year. Yet, during the three to five billions of years which the earth has existed as a solid body, the surface has not been raised by more than an inch by the addition of this star dust. Studies of the velocities of meteors show that, while some are members of the solar system, well over half come from interstellar space. Studies of the composition of meteorites reveal that none of them have an age greater than three thousand million years.

The fall of an exceptionally large meteorite sometimes leaves mute evidence of its arrival in the form of a great crater on the earth's surface. Thousands of such craters are to be seen on the moon, many of them doubtless caused by the fall of huge meteorites in the distant ages of the past.

The sun is closely surrounded by a cloud of fine particles which, during the time of a total eclipse, appears as the beautiful corona. The zodiacal light gives evidence of the extension of this cloud out beyond the orbit of the planet Mercury and perhaps even beyond the orbit of the earth. The particles of matter in the corona and the zodiacal light are in general much smaller than those producing the average shooting star.

In the space beyond the solar system some of the stars are found to be surrounded by great clouds of particles. The more symmetrical arrangements of these are called planetary nebulae and the others diffuse nebulae. Both types represent great clouds of star dust lighted by the radiation of the stars embedded in them. Great blank regions among the star clouds of the Milky Way are evidence of additional clouds of star dust so situated as to obscure the stars rather than to be lighted by them.

When telescopes are turned to an examination of the external galaxies, the so-called island universes, it is found that dark obscuring matter often appears in these systems. Hence interstellar matter, made evident by meteors in our own atmosphere, is confined not only to the solar system, or even to our own galaxy, but appears as an integral part of the whole universe as far as the telescope can reach.

Mr. A. H. Miller, the president, was in the chair and conveyed the thanks of the audience to Dr. Millman. In a brief reference to the activities of the Ottawa Centre of the Society during the past year Mr. Miller mentioned the interest that was being taken in meteor observing in Ottawa, which is a field in which the amateur astronomer, without a telescope of any kind, can make a definite contribution to the advance of astronomical knowledge. In the observation of the Perseid meteors last summer, Ottawa, among the several centres of the Society in Canada, had the distinction of having the largest number of observers. The results of their observations were regarded as specially valuable by Dr. Millman. The leaders and organizers of last year's meteor observing parties were Miss Miriam Burland and Mr. Malcolm Thomson.

Attendance about 90.

M. M. Thomson, *Secretary.*

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